ENGINEERING

An Illustrated Weekly Journal

35 & 36 BEDFORD STREET, STRAND, LONDON, W.C.2 · · TELEPHONE: TEMPLE BAR 3663

Vol. 179 No. 4662 LONDON, FRIDAY, JUNE 3, 1955 PRICE 2s.

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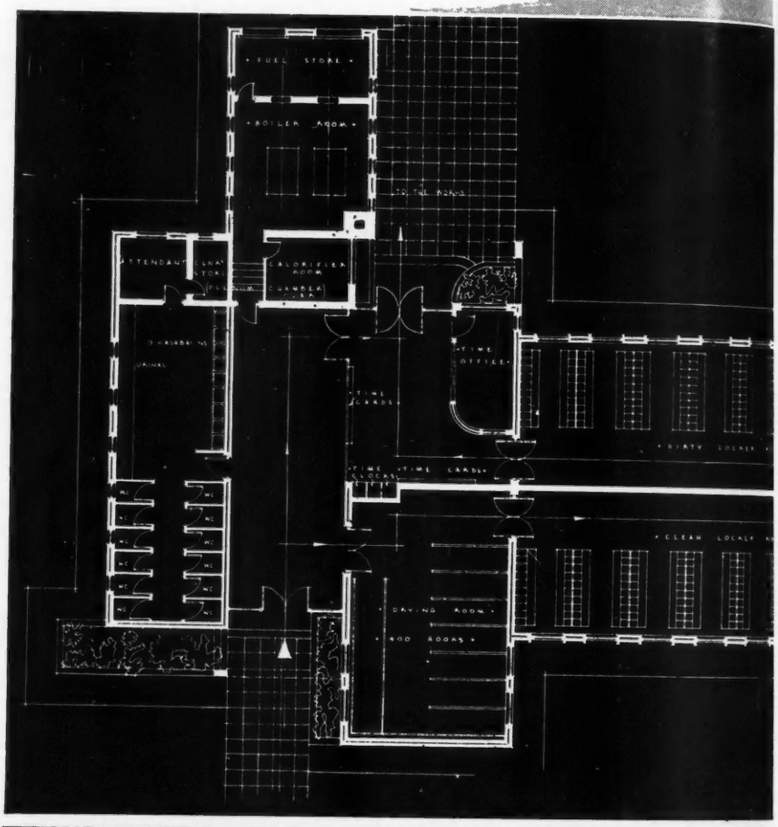

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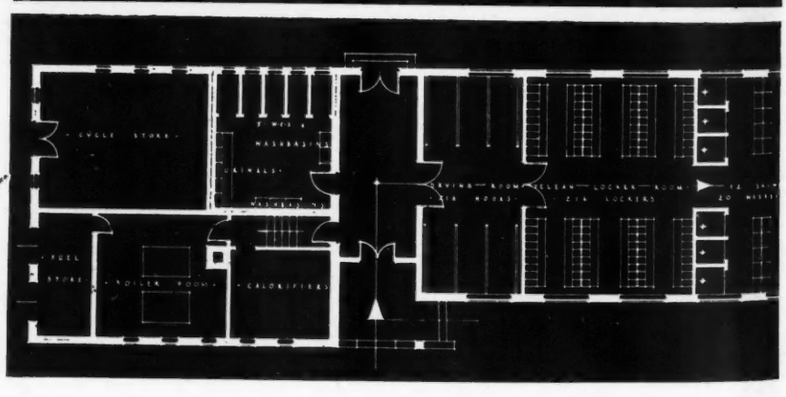

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ENGINEERING

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Published every Friday by Engineering Limited 35 & 36 *Bedford Street, Strand, London, W.C.2* TELEGRAPHIC ADDRESS *Engineering, Lesquare, London* TELEPHONE *Temple Bar* 3663

Subscription Rates for 12 *months, Inland and Abroad* £5 10*s.*, *Canada* £5 5*s. Subscriptions for periods of less than* 12 *months are based on the price of a single copy including postage* [2*s.* 3*d.*]

RELATIVE VALUES

GREAT advances in human affairs are widely recognised when they have been accomplished, but they are seen in advance only by the few who plan them. In retrospect the Battle of Britain is an epic: at the time, its real nature was known only to a few. The same is true of industrial activities. We can look back at Henry Ford, or Sir Charles Parsons, and analyse the success of his venture, but only Ford or Parsons saw the end at the beginning. Is there some principle which is common to all successful endeavours?

In mechanics the resultant of a group of forces, of various magnitudes and directions, can be found by constructing a diagram. If there is some tendency for that group of forces to act in a certain direction, then the diagram will reveal it. In human affairs the same principle applies. Given the area of activity, it is possible to determine all the elements, measure their relative values and directions, then plan the action which will succeed. The action itself may be in several parts, some directed against the external elements of the situation, others directed so as to flow with the external elements, according to the overall pattern of the plan. In mechanics it is usually possible to measure the forces with scientific accuracy, whereas in human affairs quantitative values may be hard to measure. But the principle remains —that in a given industry, or in a given profession, a successful plan comes from, first, a recognition of all the factors involved (not all will be self-evident); secondly, measurement of their values and significance (relative, if quantitative is not possible); and thirdly, formulating the plan from the data which have been collected. All this may be extremely complex. In a big undertaking it may be impossible for one person to carry it all in his head. Human relations then play a dominant part: the co-ordination of individuals becomes the plan within the main plan.

Take an actual example. One that deals with transport, and is therefore relevant to every engineering or production industry. Unilever Limited, whose products include not only margarine and Sunlight soap but also meat pies, sausages, ice-cream and fish, are directly concerned with transport. Only one day's delay in their world-wide operations would tie up another £5 million working capital. At the annual general meeting of the company last week Sir Geoffrey Heyworth, the chairman, focussed attention on transport. He illuminated a subject that is often thought to be of secondary importance. He showed, incidentally, what utter folly it is to neglect this service which absorbs or wastes so much of a nation's resources. The company's annual expenditure on transport is equivalent to nearly one-half of the total wage and salary bill of their 250,000 employees. While the labout cost of producing a ton of washing powder is 13 man-hours, the cost of delivering it 200 miles from factory to retailer may be the equivalent of 19 man-hours.

Sir Geoffrey's address was a perfect illustration of the principle of relative values. Taking all the elements of the situation he showed how they inter-acted in different ways in different parts of the world. Every sentence in the following extract from his speech is an expression of this principle:

"The nature of our products allows us to use any form of transport—rail, road, water and, in exceptional circumstances, air. Our main concern is to see that our products reach the retail shop in the proper condition, at the right time and at a price that the housewife is willing to pay. The extent to which the various forms of transport can meet these requirements differs from product to product, from country to country and from time to time. Our choice of transport therefore depends on service (which includes protection of quality, speed, reliability and regularity) and cost. It is also influenced by the handling facilities that exist at either end. At those factories and depots which were built when railways were the main form of transport, we still rely on rail to a large extent. But our policy is to adapt them so that we can secure complete freedom of choice. In the main, having decided the degree of service we require for any particular product, we then select the form of transport which provides it at the lowest cost."

This paragraph contains nothing startling or original. But it is part of a review which has clearly involved much inquiry and fresh thinking. Behind it, no doubt, is a mass of data and mathematics which have been used to enable Unilever's to plan their transport policy, in their factories and warehouses and out to their customers. Palletisation has permitted man-hours to be reduced; wage rates to be increased because greater skill and initiative are now required in the warehouses (this is a particularly important change in any country where employees expect a high standard of living; they cannot expect a high standard if they do labouring work); and total handling costs to be reduced (in one factory from 7*s.* 8*d.* to 3*s.* 6*d.* a ton). And these developments have taken place because —to appropriate one of Sir Geoffrey's phrases—"in transport as in industry a dynamic outlook is vital." It is a relative world, and the race goes to him who can see the whole pattern of relative values.

Weekly Survey

Cover Picture: *Preparing to weigh a "teapot-spout" ladle containing approximately a ton of molten metal. The metal is high-duty iron and has been held in the horizontal cylindrical receiver of 3 tons capacity seen on the left behind the ladle. The receiver is preheated by means of a gas burner inserted in the side and is replenished from a cupola behind it. The "teapot spout" of the ladle, by drawing metal from the bottom, prevents the floating slag from being poured into the mould.*

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BURDEN OF INVESTMENT PROGRAMME

Public discussion continues on how best to fit the many large expansion programmes scheduled for the next decade into the resources which can be made available to carry them out. No industry has a larger stake in the correct solution of this problem than engineering. A leading article in ENGINEERING of April 8 pointed to the numerous demands which the prospective investment programme would make on the engineering industry, and discussion since that time (which covered the period of the Budget speech) has in no way lessened this imminent problem.

The issues are extremely complex, for the engineering industry is faced not only with a possibility of conflicting claims from those industries which want new equipment to carry out major expansion programmes but also with the problem of accommodating the requirements of the home and export markets. Mr. Roy Harrod, the Oxford economist, reviewed this problem recently in an address at Buxton when he said that it was important that while British industry should modernise its capacity, it should not go forward in too much of a hurry. It was important, in his view, that all expansions should be aimed as far as possible at modernisation and should not merely reflect an optimistic view of prospective turnover. Prompt delivery was, in his opinion, vital in export markets and it would be unwise to jeopardise prompt delivery abroad by an undue swelling of domestic demand upon engineering capacity, coming from new factory building which ought to be spread more evenly over the two or three years ahead. He went on to say it was likely that the increase in Bank rate would have some effect on fixed investment before many months were out and he hinted that if it were necessary to limit commitments of the engineering industry the best place to start might be on stricter hire-purchase controls to limit purchases of goods made by the light engineering industries.

Unless there is a major crisis in the country's external trade position there is no doubt that the engineering industry overall faces one of the biggest booms in its history. If the industry's resources, however, become so stretched that it cannot supply its most important customers at home and abroad (important, that is to say, in the official view), the boom might have a rather mixed effect on engineering companies. If the Government decide to use interest rates as a means of severely restricting output in certain sections of the light engineering industry in order to move resources into other sections, many engineering firms throughout the industry might be faced with awkward problems of finance.

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MOTOR VEHICLE EXPORTS

The performance of the first four months of this year suggest that the motor vehicle industry have not been over-optimistic in their expansion schemes. An output of 400,000 vehicles of all types is about 25 per cent. higher than in the corresponding period of 1954.

Of special significance is the fact that exports increased against the rising tide of foreign competition. Car shipments rose by 18 per cent. and commercial vehicle manufacturers achieved in April their highest level of monthly exports ever. But the outlook is not quite so favourable as this picture suggests. More than half the increase in car exports was attributable to the Australian market, where import restrictions have since been imposed. Exports to the United States and Sweden were down substantially. The U.S. decline is disappointing in view of the revival of business activity. Competitors there increased their sales. The leading make in U.S. new registrations in 1954 was the Volkswagen with 6,000 units. British saloon cars of the Hillman, Ford and Austin types lost ground heavily. Registrations even of some of the sports cars fell. Others, such as the Austin-Healey and Triumph TR2, however, did well and it is upon these that it seems the British attack on the U.S. market must depend. The Nash Metropolitan car made by the British Motor Corporation for the Nash company will, of course, give a solid foundation for British exports, but this car, designed for the American family market and with a large American sales and service organisation behind it, is in a special position. The Germans, on the other hand, are making headway with a standard production car which will sell in many markets. Their success in the U.S. implies that they can outsell most British cars in all markets where these have no special advantages; and this seems to be confirmed by the trend of sales in Europe. This generalisation, of course, obscures the success of particular makes of British car, sales of which have continued to increase in Europe in direct competition with the Volkswagen. It underlines, however, the importance of founding the British expansion programmes on really good cars with the widest possible appeal.

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CARS IN AUSTRALIA

Australia is one of the most important of the world export markets for cars. New registrations are running at about 150,000 per annum. Of a total Australian hire-purchase expenditure of £223·8 million in 1954, £169·9 million was on cars, commercial vehicles and motor cycles. Large imports of cars tend to strain the chronically precarious Australian balance of payments, and it is natural enough that restrictions should be imposed on them (as at present) whenever a crisis occurs.

It is the policy both of the Australian authorities and of foreign car makers to circumvent these difficulties by undertaking the assembly and manufacture of cars in Australia on an increasing scale. Of the British cars sold in Australia in 1954, 79 per cent. were assembled there compared with 46 per cent. in 1950. Moreover, the proportion of parts made in Australia is growing. One car, the Holden, of General Motors (Holden), Ltd., has almost an entire Australian content. An expansion plan costing £3 million was announced last year to raise output from 240 to 300 cars a day. Another American concern, American Motors Corporation, have now announced their intention of building Hudson cars in Australia in the next five years. Initially, an assembly plant is to be established, but the complete manufacture of the Hudson car is contemplated. The Chrysler Corporation are also to expand their assembly capacity in Australia and hope eventually to employ 7,000 people. Such an extension of American interests is obviously a threat to British exports, and the most natural counter is to expand British assembly and manufacturing capacity there.

Among the British companies taking this course are B.M.C. and Rootes, although of course Ford and Vauxhall benefit from the Australian facilities set up by their parent American companies. B.M.C. announced a large-scale expansion scheme last year involving production of 50,000 Austin and Morris engines per annum. For the Rootes expansion recently announced an 83-acre factory has been bought, and the first stage includes the manufacture of engines for Hillman Minx cars. Though all this development in car manufacturing is carried out chiefly with foreign capital, it can hardly be to the best interest of the Australian economy to tie up such large human and material resources in the manufacture of consumer goods of this kind. Comparable development in "resources" industries on the other hand might go far to solving the balance of payments problem.

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COPPER AND CABLES

Many factors contributed towards the difficulties experienced by cable makers last year. At the beginning of 1954 demand was extremely sluggish, and although it has since revived so considerably that overtime working is common, the unevenness of the load throughout the year reduced profitability.

The growth of local production in the principal export markets and rising European capacity are not new factors, but their effects were particularly marked in 1954. Increased competition at a time when the price of copper, the industry's principal raw material, was rocketing prevented the cable makers from raising their own selling prices proportionately. Copper is perhaps the biggest of the industry's problems at present. The immediate outlook for cables on the sales side is good. As Mr. W. H. McFadzean, chairman of British Insulated Callender's Cables, Limited, pointed out in his recent report, the cable industry as members of the electrical industry must in the long run expect an expanding demand for their products. The price of copper, however, continues to rise and the fluctuations this year have been much more than last. Firms like B.I.C.C. have to accept the full risk arising from these fluctuations. The consumer of the finished product can hold off when prices are high and buy when they fall: the cable maker must always have enough copper to keep his works running. The recent agreement with Rhodesian Selection Trust, by which that company has undertaken to supply copper to large consumers including B.I.C.C. at fixed prices periodically revised, will give some stability—although the other Rhodesian copper producers have not followed the R.S.T. example. B.I.C.C.'s influence in Rhodesian copper has been increased by the investment of £1 million (one-third of the share capital) in Ndola Copper Refineries, Limited. The remaining two-thirds are being subscribed by Roan Antelope Copper Mines, Limited, with whom B.I.C.C. have a long-standing association which dates back to the founding of their subsidiary, British Copper Refiners, in 1932. B.I.C.C. have welcomed the opportunity both of strengthening this association and of obtaining a direct share in an electrolytic refinery.

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BRITISH OXYGEN RE-ORGANISE

The British Oxygen Company, Limited, are extremely cautious in forecasting their prospects for 1955. In his recent statement, Mr. J. S. Hutchison, the chairman, looks forward to a favourable result but lays heavy emphasis on rising costs. A large increase in the sales of industrial gases is expected but these will lie mainly in the large-quantities category where prices are keenest. Moreover, the increased supplies will derive from costly new plants which will take time to settle down to optimum working.

No great change is consequently expected in the results of the Industrial Division during the current financial year. B.O.C. are, however, on the threshold of a period of intensive development and great opportunity. To make the most of it requires initiative and resourcefulness and it is the object of the company's re-organisation scheme to give the fullest scope to these qualities in their management. The segregation of all operational activity under appropriate subsidiaries will both give more adequate responsibility to the operational executives and give the directors on the parent company board more effective freedom for the planning and

general guidance of policy. The new developments include the supply of "tonnage" oxygen, requiring the erection of plants with capacities of 100 to 200 tons per day (1 ton = 26,000 cub. ft.) sited specially to meet the needs of steelmaking, chemical manufacture and coal gasification (see ENGINEERING, January 28, pages 99 and 122). The quantity of oxygen supplied in liquid form (suitable for consumers taking from 20,000 to 2 million cub. ft. a week) is also increasing in relation to the less economic high-pressure cylinder supplies, which must nevertheless be used for small or intermittent demand. Prospects for liquid oxygen, particularly as an oxidant in bi-fuel rocket aircraft engines, are very bright. B.O.C. have carried out considerable development work in close association with the Ministries.

The increasing use of large-scale oxygen supplies opens up a large market for producing plants, for the development of which B.O.C. (jointly with the Gesellschaft für Linde's Eismaschinen) have set up a new sales company, British Oxygen Linde, Limited. This company can offer air-separation equipment of the most advanced types including tonnage oxygen and nitrogen plant. Other extending fields for B.O.C. include plastics. The success of melamine as a raw material for the plastics industry has led to a decision to double capacity. B.O.C.'s plant for the manufacture of polivinyl acetate recently began production. Mr. Hutchison states that sales of welding electrodes unaccountably seem not to respond fully to the general activity of the engineering industry. This must however, be a temporary phenomenon, and in welding plant, too, the opportunities for B.O.C. are increasing.

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STEEL BOARD'S FIRST REPORT

The Steel Board's first report (covering the period from July, 1953, to December, 1954) is a tantalising document. It tells so much, and yet so little. In a comprehensive survey covering its responsibilities for the iron and steel industries' development, costs and prices, import duties, international relations and labour and welfare, one of the most interesting sections is that on how it fixes steel prices. Many people would like to know how they are charged for their steel. They will come away with mixed feelings from a reading of this report (H.M. Stationery Office, 1*s.* 3*d.*). They will have to admit that they are given a clear exposition of the principles on which steel prices are fixed but they will not have a very clear idea how they are fixed. For instance, there is a lucid account of the principle that profit margins are based on capital employed in the companies but we are not told what the margins are.

To be fair, it has to be admitted that the board is feeling its way. It has been given ultimate control of development plans and it fixes maximum prices. These are powerful instruments of tutelage and doubtless the board is very conscious that it is pioneering a system of state supervision which avoids nationalisation and must be made to preserve features of competition. It may yet be said that this form of control is more effective than nationalisation and yet avoids wasteful cut-throat competition in heavily capitalised industries. The search for sound principles is therefore understandable.

The principles evolved for fixing prices will, of themselves, raise more discussion among accountants and economists than among engineers. The more important ones may be briefly mentioned. In addition to the basis for profit margins mentioned above, operating costs are fixed on a "reasonable" basis (being based neither on the highest nor lowest cost producers) with an incentive to increase profits by cutting costs. Depreciation charges are based on Inland Revenue allowances (which are on the low side) and the price for steel contains an element to enable companies not only to reserve for wear and tear but also an allowance "to ensure that the efficiency of the industry—and therefore in the ultimate the continuity of its operations—should be maintained." Finally, home prices are neither to subsidise nor be subsidised by export prices.

All in all, the steel user will be prepared to wait a little longer to see how this tidy world works out in practice. At present it has a faintly cosy atmosphere. In due course, he will want to know rather more about how these components of steel prices move and he will be following them with interest in comparison with the annual accounts of the iron and steel companies.

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THE GERMAN PHOENIX

A short visit to a foreign country gives only the most superficial impression, but the senses are so alive to the new surroundings that such a visit gives proportionally more information and atmosphere than a visit of a month or a year. A recent trip to Essen, Düsseldorf and Frankfurt presented the opportunity to compare Germany in 1955, with Germany at the end of the war (in 1945), and in 1950 when working as a student in a German factory.

In the three cities the overwhelming impression was one of astounding prosperity. The lights in the Königsallee in Düsseldorf blaze on to the hundreds of cars and the profusion of goods in the shop windows, and the whole city seems to throb with life. This prosperity is built on the heavy industries of Germany, and particularly of the Ruhr. Many of the factories were flattened by bombs or by the subsequent dismantling for reparations, and the engineers were able to plan new factories to fit their production requirements, and make the most of their chance to use modern techniques of construction and layout.

Several factors seem to have helped the Germans in their recovery, among them the freedom from arms production, which has taken up such a large portion of the resources and energy of other countries since the war; the factories planned and rebuilt to present-day requirements; a government policy aimed at furthering the expansion of heavy industry, the bed-rock of the whole German economy; hard work and good organisation by the planners, directors and engineers; hard work by the factory hands.

An indication of the importance attached to industrial development by the Germans is the Haus der Technik, at Essen. This is a meeting place for engineers and industrialists, with three large halls which can be used for lectures or conferences. It is not part of a technical school, and is seldom used for lectures to students only. That such a building should have been put up in spite of the competing claims of housing and new factories shows how necessary the Germans think it is to have frequent technological discussions, and to learn the results of new research and production techniques.

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FAILURE OF A FAIR

The British Industries Fair which ended on May 13 produced so much more than its average crop of criticisms that the time may be appropriate to ask what it sets out to achieve, and how far it succeeds. Originally, the B.I.F. was held to exhibit the products of British industry, pending the development of specialist exhibitions in the aftermath of the war. It was to be a general shop window in which foreign buyers could see in two main centres the products of manufacturing industry. This year, the sections that interest our readers most—Engineering at Castle Bromwich and Scientific Instruments at Olympia—were most disappointing and anything but cross-sections of these industries' products. For example, there were no machine tools, heavy oil engines, heavy electrical plant or railway plant, and there were many other gaps. It may be that the organisers of specialised exhibitions, such as those for machine tools, motor vehicles, engineering and shipbuilding, textile machinery, mechanical handling and others, actively discourage their members from exhibiting at general trade fairs. Whether this is so or not, many companies exhibited only part of their range of products, and the exhibition was in this sense most unrepresentative and misleading for overseas buyers.

The consensus of opinion reaching us certainly supports the view of the writer of a letter to *The Times*, that the B.I.F. was "a hopelessly inadequate venture." There is evidence that engineering manufacturers are not looking to the Fair to show their new products. There is also evidence that exhibitors are not putting their best foot forward to publicise their products. The general standard of Press information was pathetic, and attendance on the stands not good. The new organisers of the Fair have hardly had time to effect any marked improvement, but there there is no altering the fact that some of the major engineering industries must necessarily exhibit at their own specialised exhibitions in this country, and in similar exhibitions on the Continent; and that after participating in these shows it is not prudent for many of them to take a stand at the B.I.F.

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ALUMINIUM WONDERLAND

It seems possible that since its inception one hundred years ago the British aluminium industry has taken one or two sips from Alice's bottle, for during that time it has grown at a pace which even Alice herself might have found surprising. But unlike Alice, the aluminium industry has with increasing stature proved capable of passing through an ever greater number of doors, and through them it has entered such fields as structural, mechanical, electrical and marine engineering, railways and road transport, packaging, the food industries, prime movers, aeronautics and mountaineering.

To commemorate the aluminium industry's century of fruitful and prolific growth since the first particles were separated in this country, the Aluminium Development Association are holding an exhibition at the Royal Festival Hall, Waterloo, and current uses of aluminium and its alloys are well represented.

To-day (Friday, June 3) H.R.H. The Duke of Edinburgh is to visit the exhibition, which opened on Wednesday, June 1, and will close on Friday, June 10. Except on this occasion, not only potential users of the metal but also members of the public are being admitted, and exhibits include vessels moored in the River Thames and large structures erected in the forecourt of the Festival Hall. During the period of the exhibition a series of discussions are being held and these will deal with various fields of application of aluminium.

The many uses of this metal arise from its unusual combination of properties, and in recent years the development of the Argonarc welding process has added to the usefulness of aluminium since large-scale fabrication is now possible. This is well illustrated by its use on the liner "United States" which employs in its superstructure some 2,000 tons of the metal. Other applications range from deep-drawn milk churns to bridges and gas-turbine air impellers. Lightweight machine tools, heat-reflecting clothing, building construction, and railway coaches are further examples of its use. It is likely that aluminium will play a considerable part in national road and rail development programmes.

Future trends may be gathered from past experience and between 1948 and 1953 the production of aluminium in Britain was doubled. Hydro-electric power may provide an ever-increasing yield of aluminium from its ores, and a prescient Alice visiting the exhibition may see in it the prospect of a wonderland of aluminium ahead.

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We regret that deliveries of ENGINEERING *are likely to be delayed as a result of the strike on British Railways.*

SCIENCE AND ENGINEERING

CONVERSAZIONE AT THE ROYAL SOCIETY

The dignified and beautiful rooms of the Royal Society provided a fitting background to the Conversazione which was held on May 19, a number of interesting scientific exhibits being shown. All the 36 exhibits were of interest, but some have previously been described in ENGINEERING and some have only limited application to engineering. Two of the most unusual, which are described below, showed how a spider builds his web and how whales hear. Both animals have problems which could be solved by engineering techniques, but their solutions are instinctive; it is, however, from the observation of such natural phenomena that many scientific and technological advances have been made.

THE SPIDER AS AN ENGINEER

The construction of an orb-web, which can be seen iridescent with dew in the early mornings of the summer, takes between 25 and 50 minutes. The spider begins by throwing out a thread which becomes entangled in grass or in a bush. He tests the strength of the thread, and when he knows it will bear his weight he travels backwards and forwards along it strengthening it by adding more threads. From this bridge thread the same process is repeated until he has built up a frame; across this frame he makes radii, by attaching a filament to one point, taking it round to the opposite side of the frame, and pulling it taut. In this way he makes perhaps 30 radii, and then starts to make the dry or temporary spiral on the radii. Starting from near the hub of the web he moves outwards until the distance between radii becomes too great for him to span. He then continues round the web, but now working his way back to the centre; as he does so he lays down a viscid spiral, made from thread coated with a sticky substance to trap his victims, and takes up and discards the temporary spiral. He is certainly fortunate that his material presents him with no supply problems, and that it is so eminently suited to its purpose.

The exhibit showed the various stages in web construction, and was made by Dr. G. O. Evans and Mr. Macer-Wright, of the British Museum (Natural History).

ACOUSTIC PROBLEMS OF THE WHALE

It was thought for a long time that whales could not hear at all or only imperfectly, but it has now been established that their hearing is acute and sensitive to a wide range of frequencies. Since they are mammals and their essential organ of hearing is as in other mammals they are faced with four problems.

They must convert water-borne sounds to the same kind of air-borne vibration as is experienced by land mammals. They do this by reducing the pressure and increasing the amplitude of the vibrations. The pressure is diminished by the great reduction in area of the tympanic membrane which is drawn out into a thin ligament instead of being an "eardrum." The amplitude is increased by making this ligament act like the piston rod on the cam-like hammer of the middle ear. The direction of the sound origin is determined by placing the essential organs of hearing widely apart for fine discrimination of phase or intensity difference.

The whale must prevent sounds from being carried through the body to the inner ear by channels other than the external ear passage. This is done by the inner ear being separated from the rest of the skull and surrounded by a sound-insulating layer of foam contained in large reservoirs connected with the middle ear. Pressure in the middle ear must be regulated at all depths of the ocean. The reservoirs containing foam also form a source of gas for balancing the pressure on the inner side of the ear drum with that outside in the surrounding water.

The exhibit consisted of models and drawings which clearly showed the problems and their solutions; it was shown by Mr. F. C. Fraser and Mr. P. E. Purves, Department of Zoology, British Museum (Natural History).

FRICTION AND FLOW PROBLEMS

Problems in friction were the subject of the exhibit by Dr. F. P. Bowden, F.R.S., and Mr. E. H. Freitag, Department of Physical Chemistry, Cambridge. The apparatus used by Dr. Bowden was described in his Thomas Hawksley lecture, delivered on December 17, 1954, an account of which appeared in ENGINEERING for December 24, 1954 (vol. 178, page 814). The account contained only a brief mention of some experiments conducted into the performance of skis, which formed part of Dr. Bowden's researches.

The sliding friction on snow and ice is very much lower than that of most other crystalline solids. There is evidence that in ski-ing, in sledging and in sliding on ice and snow this low friction is due to a water film produced by frictional heating at the points of rubbing contact. This causes a local surface melting of the snow crystals and the formation of a water film which acts as a lubricant. At low temperatures this surface melting cannot occur, and the friction is very high, similar to that of dry sand. Recent experiments have shown that the material polytetrafluoroethylene (P.T.F.E.) gives a very low friction under all conditions on snow and ice. This is partly due to its inherently low friction and partly to the fact that it is not wetted by the water film. Skis coated with P.T.F.E. have been used on timed descents in the Alps. A run on a gentle slope 700 ft. long with air temperature at 5 deg. C. and snow temperature at 0 deg. C. took 61 secs. using conventional skis coated with Norwegian wax and paraffin, and 42 secs. using the skis coated with P.T.F.E.

The exhibit shown by Mr. N. Gregory, Mr. J. T. Stuart, and Mr. W. S. Walker, Aerodynamics Division, National Physical Laboratory, illustrated the instability of the laminar boundary layer on a rotating disk, a phenomenon which also occurs in the flow over the swept wings of modern aircraft. Part of the drag of a wing arises from the fact that a thin layer of fluid, known as the boundary layer, is dragged along with the wing by frictional forces. Within the boundary layer, the flow may be either in streamline (laminar) motion or in disordered (turbulent) motion. Because of the large dissipation of energy in turbulent motion, the drag is much greater; consequently it is desirable that transition from laminar to turbulent motion should occur as far back on the wing as possible.

On a swept wing, however, transition takes place very close to the leading edge. Recent wind-tunnel and flight experiments revealed that this was due to the growth of self-amplifying vortices in the three-dimensional boundary layer over the nose of the wing. An analogous flow occurs on a rotating disk, and in this case the instability which causes the vortex growth is more easily studied.

On the disk, the main flow is due to the tangential motion of the disk surface. A secondary flow occurs at right angles to this because of the lack of balance of forces within the boundary layer. This secondary motion is unstable, and over a certain portion of the disk a vortex motion arises, the individual vortices having a spiral form. Nearer to the centre of the disk the flow is laminar, while farther out it is turbulent. This is demonstrated acoustically by means of a stethoscope. In the laminar region, no sound is detectable; in the vortex region, the rapid succession of vortices passing the stethoscope probe produces a note of fairly definite pitch; and in the turbulent region, a confused roar is heard, caused by the random turbulent fluctuations.

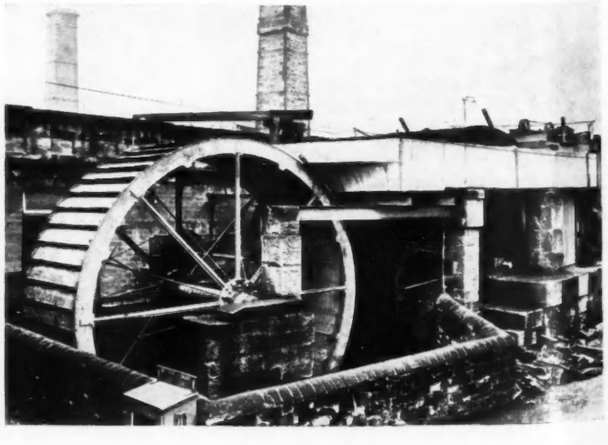
The subjects of a number of other exhibits have previously been described in ENGINEERING. Among these were: model of an Andreau windmill, shown by the Chief Engineer's Department, Central Electricity Authority, described in the issue of March 25, 1955, on page 179; vapour-phase chromatography, shown by Imperial Chemical Industries, Limited, described in the issue of May 28, 1954 (vol. 177, page 677); an animated diagram illustrating the chain reaction in a nuclear reactor, shown by Dr. F. A. B. Ward, of the Science Museum (the reaction illustrated was described in the issue of September 11, 1953 (vol. 176, page 745)); a model of the experimental heat pump installed at the Royal Festival Hall in 1951, shown by the Science Museum, and described in the issue of June 22, 1951 (vol. 171, page 741).

* * *

OBITUARY OF TWO WATER WHEELS

For more than a century, the power required by what is now the Bakewell, Derbyshire, factory of the D.P. Battery Company, Limited, has been provided by two water wheels of rather exceptional size; but now, following a serious breakdown of the larger of the two wheels, it has been decided to replace them by a water turbine. The factory, originally a cotton mill founded in 1777 by the famous inventor Arkwright, later Sir Richard Arkwright, was taken over by the D.P. Battery Company in 1898; incidentally, the initials "D.P." indicate the names "Dujardin-Planté," and so are historical in themselves. The larger wheel, measuring 25 ft. in diameter and 18 ft. wide, was built by the Manchester firm of Hewes and Wren in 1827; it had 70 buckets and these, in ordinary working, held 10¾ tons of water.

The smaller wheel, constructed in 1852 by



This illustration shows the two historic water wheels outside the premises of the D.P. Battery Co. Ltd., at Bakewell, Derbyshire, soon after they broke down. On the left is the 1852 wheel and on the right the larger 1827 wheel. In the right foreground can be seen some of the segments removed after the breakdown earlier this year. Both wheels will now be dismantled and replaced by a modern water turbine.

Kirkland and Son, of Mansfield, measured 21 ft. in diameter by 7 ft. wide. Like the larger wheel, it had become, with the passage of time, almost an object of veneration; in fact, during the past nine years the firm have spent some £8,000 on repairs and replacements on the two wheels, in the hope that they would continue to provide the necessary power, amounting to between 60 and 80 kW, according to the supply of water available. Early in the present year, however, one of the teeth on the larger wheel broke and jammed against the pinion—nearly 5 ft. in diameter and 14½ in. wide—which transmitted the power to the shafting in the mill. As a result, all the pinion teeth were stripped away, together with many of the teeth on the wheel, and the frame of the wheel and that of the driving wheel inside the factory were also broken. In the circumstances, it was realised that to repair the damage was out of the question, and reluctantly it was decided that the historic wheels must be scrapped.

When, in 1934, the Newcomen Society visited the works, the larger wheel was running at 4 r.p.m., and the two together were stated to be developing 125 h.p. This may have been merely an estimate; but a more precise test of the big wheel's performance was made in August, 1951, particulars of which were supplied to the Society for the purpose of historical record. On that occasion, the revolutions were 2·613 per minute, the torque due to the weight of water was 240,218·5 lb.-ft., and the corresponding horsepower was calculated to be 119·56, giving an efficiency of 73·7 per cent. The wheel had an axle of cruciform section and a rim constructed in ten segments, each having 27 teeth. The teeth on the pinion numbered 57. They had a pitch of 3·113 in. and a depth of 2¼ in.

In the April, 1955, issue of *The Newcomen Bulletin*, published by the Newcomen Society, the wheels were described as being overshot, but in fact they were breast wheels. At one time, their speed was regulated by a governor of the type described by Sir William Fairbairn, which still exists but has been long disused. In practice, the flow of water was regulated by a series of louvres, operated by a rack-and-pinion gear. The smaller wheel, like the larger, had a rim of internally-toothed cast segments and wrought-iron spokes, with diagonal internal bracing. The shaft of the smaller wheel was circular in cross section.

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ANTOINETTE MONOPLANE FOR SCIENCE MUSEUM

Successful Machine of 1910

Through the generosity of Mr. Robert Blackburn, chairman of Blackburn and General Aircraft, Limited, the Antoinette monoplane on loan to the Science Museum since 1926 has been presented for permanent inclusion in the National Aeronautical Collections.

This aircraft, of French design and manufacture, is known as the "Antoinette 1910 Model," and is the only complete one of this make and type now in existence. It was brought to this country by Hubert Latham in 1910 subsequent to his attempts to cross the English Channel with earlier types of this machine.

The Antoinette was recognised during its time as being not only beautiful in design and graceful in flight but capable, unlike most machines of the period, of flying in bad weather. This was ably demonstrated by Latham at the first Blackpool Air Meeting, in 1909.

The Antoinette, together with the Bleriot, successfully established the now conventional form of monoplane with tractor airscrew and tail-plane. An estimate made in early 1911 gave the numbers of these aircraft built to this date as 47 Antoinettes and 158 Bleriots, representing together about 30 per cent. of the total number of aircraft then in service in France and England.

PERSONAL

MR LESLIE GAMAGE, vice-chairman and joint managing director of the General Electric Co. Ltd., has been re-elected President of the Institute of Export for the 13th year in succession.

SIR SUMMERS HUNTER is relinquishing the position of managing director of Richardsons, Westgarth & Co. Ltd. (Parent Company) on July 31, on reaching the Group's retirement age. He will remain a member of the board and his services will continue to be available in a consultative capacity. MR. J. R. MACKAY, at present deputy managing director of the Parent Company, has been appointed managing director with effect from August 1.

EMERITUS PROFESSOR W. R. JONES, C.B.E., D.Sc., D.I.C., past President of the Institution of Mining and Metallurgy, Salisbury House, Finsbury Circus, London, E.C.2, has been awarded the Gold Medal of the Institution. The honorary membership of the Institution has been conferred upon MR. G. A. DENNY and DR. J. B. TYRRELL, M.A., B.Sc.

THE MINISTER OF SUPPLY, with the agreement of the Secretary of State for War, has appointed BRIGADIER W. S. KING, C.B.E., to succeed BRIGADIER F. W. GORDON-HALL, C.B.E., as director of Inspection of Fighting Vehicles, with effect from August, 1955. BRIGADIER J. L. MORTON will succeed BRIGADIER W. S. KING as deputy chief engineer, Fighting Vehicles Research and Development Establishment, Chertsey.

MR. H. J. D. KEARNS, B.A., A.M.I.Mech.E., who has been a director of H. W. Kearns & Co. Ltd., Altrincham, Cheshire, since 1941, has been appointed joint managing director with the chairman, SIR LIONEL KEARNS, C.B.E., B.A., M.I.P.E. MR. C. A. SPARKES, chief designer, has also been elected to the board and has special charge of designs and development.

MR. JOHN CHAPLIN, A.M.I.Mech.E., has joined the executive staff of the chemical-plants department of Blaw Knox Ltd., 94, Brompton-road, London, S.W.3. This department was inaugurated in 1954 to manufacture, in Great Britain, the BUFLOVAK range of equipment previously only available from the United States.

MR. R. T. COLLINS has been appointed senior project engineer (Midlands), and MR. G. H. DUFFIELD, A.M.I.Mech.E., senior project engineer (Northern), Sharples Centrifuges Ltd., "Tower House," Woodchester, Stroud, Gloucestershire. MR. M. W. VINCENT, B.Sc., A.R.I.C. is to be concerned with all aspects of project development work in the firm's Tower House laboratories at Stroud.

GENERAL SIR KENNETH NOEL CRAWFORD, K.C.B., M.C., has been elected to the board of Westland Aircraft Ltd., Yeovil, Somerset.

Leverhulme Research Awards for 1955, have been made to DR. P. F. R. VENABLES, B.Sc., F.R.I.C., Principal, Royal Technical College, Salford, for research on training schemes in certain industries, with special reference to the work of technical colleges and the needs of smaller firms; and to MR. L. W. DERRY, M.Sc., F.I.M., head of Department of Metallurgy, Battersea Polytechnic, and MR. E. W. WILKINS, M.A., M.I.A.S., F.R.Ae.S., of the Royal Aeronautical Society, for a joint statistical investigation into the fatigue properties of certain non-ferrous metals.

MR. D. R. S. TURNER, B.A., A.M.I.E.E., has been appointed manager of the Larne Works, Northern Ireland, of the British Thomson-Houston Co., Ltd., Rugby. MR. S. J. CLARKE, T.D., Assoc.I.E.E., has been made manager of the firm's Manchester district office in place of MR. F. C. BARFORD, T.D., M.I.E.E., who is to be manager, Birmingham district office, with effect from June 15. Mr. Barford is replacing Mr. J. CLEMENT who is shortly to take up another position within the B.T.H. organisation.

MR. H. MELTON has been appointed in charge of the apparatus and equipment development engineering department of Ericsson Telephones Ltd., Beeston, near Nottingham.

MR. D. H. BROWN of the English Electric Co. Ltd., has been appointed, by the Northern Ireland Ministry of Commerce, to the new post of engineer in charge of plans for the use of nuclear energy in the generation of electricity.

MR. W. F. CROWTHER has been appointed manager, Hull sub-office, and MR. J. S. HALL, assistant manager, Manchester office, of the Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.

MR. SEAN MACENTEE, T.D., has been elected to the board of Brush Aboe (Ireland) Ltd., the Irish subsidiary company of the Brush Group Ltd.

Birlec Ltd., Tyburn Road, Erdington, Birmingham, 24, have recently joined A.E.I. Limited. They also announce the appointment of MR. K. L. MOON as sales manager of their induction heating division. MR. A. E. PICKLES continues as manager of the division, with overall responsibility, and MR. R. ABBOT as technical manager. Birlec Ltd., also announce the appointment of MR. H. J. PODMORE as sales manager of their specialist dryer division. MR. T. C. SANDERS continues as manager, with overall responsibility, and MR. J. W. CARTER as technical manager of the Division.

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COMMERCIAL

R. A. DYSON & CO. LTD., trailer manufacturers and engineers, Grafton-street, Liverpool, 8, have moved their London office from 103, Cannon-street, E.C.4, to Dashwood House, 69, Old Broad-street, E.C.2. (Telephone: LONdon Wall 5392-3.)

AEREX LTD, Cavendish Buildings, 220, West-street, Sheffield, 1, and F. H. BIDDLE LTD., 52, Clerkenwell-close, London, E.C.1, have entered into an agreement whereby the latter firm is appointed sole selling agent for Aerex duct axial fans to firms engaged in the supply of heating and ventilating equipment, refrigeration and air-conditioning equipment, together with consulting engineers and architects engaged thereon, and to oil companies throughout the United Kingdom and Eire.

The Scottish office and service depot of the ATLAS DIESEL CO. LTD., has been moved to larger premises at 591 Nitshill-road, Glasgow, S.W.3. (Telephone: Barrhead 2346–8). The South Wales office has likewise been removed to 27, Wyndham-crescent, Cardiff. (Telephone: Cardiff 31161–3).

THE DAVID BROWN COMPANIES, Huddersfield, announce that their industrial tractors and ancillary equipment are now being marketed in Eire by DAVID BROWN TRACTORS (EIRE) LTD., 25–29, Upper Dominick-street, Broadstone, Dublin.

W. RALSTON LTD., marine and industrial photographers, have moved to larger premises at 334, West George-street, Glasgow, C.2 (Telephone: Central 3061-2).

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CONTRACTS

Railway Track Switches. Some 430 sets of three different types of standard railway switches are to be supplied during the next three years by the trackwork department of EDGAR ALLEN & CO., LTD., Imperial Steel Works, Sheffield, 9, for use on the main lines of the Argentine National Railways. The switches will be built up from rolled manganese-steel rails weighing 100 lb. a yard, and will be supplied complete with the necessary chairs and small fittings.

Destroyers. An order from the Chilean Government for the construction of two destroyers has been received by VICKERS-ARMSTRONGS LTD., Vickers House, Broadway, London, S.W.1. The two vessels will be built at the Barrow shipyard and their propelling machinery and armament will also be supplied by the firm.

Electric Railway Traction Equipment. The British Transport Commission have placed an order for the complete traction equipment of 57 new three-coach multiple-unit electric-train sets with the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2. They are to replace existing rolling stock on the Euston-Watford service of the London Midland Region of British Railways. Each three-coach set will consist of a motor coach, trailer, and driving trailer. The rolling stock, to be built in the British Railways workshops, will be of the compartment type with central corridor. The Euston-Watford line is electrified on the third and fourth-rail system at 630 volts direct current. Each motor coach will be equipped with four axle-hung self-ventilated motors of 206 h.p., at the one-hour rating. The value of the order is approximately £741,000.

Electric Transmission Line. An order from the Central Electricity Authority for the erection of a further 92-mile length of 275-kV transmission line between Hams Hall, Birmingham, and Melksham, Wiltshire, has been received by BRITISH INSULATED CALLENDER'S CONSTRUCTION CO. LTD. The work is due for completion by October, 1956.

Storage Platform Material. The materials-handling division of FISHER AND LUDLOW LTD., Birmingham, have received a contract from the United States Army Air Force in France for the supply of 500,000 lineal feet of "Flowstrut" slotted-angle material and 120,000 sq. ft. of "Flowforge" open steel flooring material for the building of storage platforms.

THE PROFESSION OF METALLURGY

SUGGESTION FOR A HIGHER AWARD

The Presidential Address to the Institution of Metallurgists was delivered in London by Professor F. C. Thompson, D.Met. (Sheffield), M.Sc. (Manc.), B.Sc. (Lond.), on Wednesday, May 25. Professor Thompson occupies the Chair of Metallurgy in the University of Manchester. An abridged version of his address, which dealt with metallurgy in the modern scientific world, appears below.

Although the boundary may not always be sharply defined, the scientific field of the metallurgist is sufficiently clearly outlined for the subject to be legitimately considered as a specific and distinct branch of knowledge. For a science to justify a separate existence as such, however, it must make its own contribution to the general pool of scientific fact and hypothesis. To what extent can this be claimed for our own ? That the metallographer has made a most important contribution to our knowledge of the solid, i.e., the crystalline, state, there can be no reasonable doubt. The field of rheology, for instance, has been immensely enriched by studies of the deformation and flow of the metals; and the similarities for instance between these and the deformation of synthetic fibres, although there are most important differences, are still quite striking.

How much modern engineering progress owes to work in metallurgical laboratories, and the extent to which further advances are awaiting new alloys for their exploitation, are sufficiently well known to need no emphasis here. In the field of nuclear engineering, the responsibility of the metallurgist—in part one of a rather new type—both for the speed and the success with which the new possibilities are rendered available to human needs requires no embroidering. If the range of materials now available to the engineer be compared with those at his disposal fifty years or so ago, the contribution of our science to the material as well as to the scientific progress of mankind will be appreciated.

The petrologist can, and has, given first-rate help in the study of ores, slags and refractory materials, while the metallurgist's study of the constitution of slags and their reactions may well provide the key to certain problems of the geologist's magmas.

NEW ALLOYS FOR HUMAN WELFARE

The importance of the stainless steels and still newer materials such as tantalum, and more recently zirconium, to the surgeon, and the highly specialised range of alloys now at the disposal of, or under investigation by, the dental profession, illustrate the assistance which has and is being given in a sphere of activity of most direct importance to human welfare. In the treatment of certain types of malignant disease, the γ radiation, for which Au^{198} is an obvious source, is required. Along with γ radiation this gold, however, emits the β form which must be filtered out to avoid severe local damage to the tissues. It is to the metallurgist that the solution of this problem is due, by coating the seeds of gold with a platinum sheath sufficiently thick to absorb the β radiation emitted after irradiation of gold with neutrons.

In relation to the chemical sciences the outstanding contribution which the metallurgist has made, at any rate on the more technological side, has been the discovery of the corrosion-resisting alloys, and the explanation, and therefore the elimination, of the serious defects from which the earlier steels suffered.

GROWTH OF INSTITUTION

When the Institution was first founded, there were those, of whom I was one, who believed that it would experience a few years of prosperity and rapid growth while its initial membership was being recruited, but then feared a period, perhaps a somewhat prolonged one, of relative stability until, as it approached a state of maturity, a second, but slower, stage of growth as an established organisation set in. As things have turned out this opinion has proved to be far too pessimistic. Growth has been continuous, and shows little sign of approaching any asymptotic value for many years to come.

It would seem to me that our marked success so far—and that success has been greater than many of its founders could ever have anticipated—provides abundant justification for the policy of the Institution in requiring a breadth of knowledge and experience from its members.

SUGGESTED DIPLOMA

With the growth of all sciences and technologies, the time comes when the individual must, however unwillingly, devote his thought and work more and more to some relatively restricted section of his field. Has the time now come when this Institution might take into its consideration the encouragement of what I may term post-graduate studies, by the award of a diploma or other qualification to those who, in addition to the broad training—for which I have already pleaded—have made such further, specialised study of some one of the main branches of our science that they can be regarded as masters in it?

I must, however, stress as strongly as it is possible to do that what I am about to say must not be regarded in the slightest degree as representing the opinion of the Council, or, at the present stage, of doing more than put into words an idea which has been in my mind for some little time. Further, it must be stressed that the idea, if it were decided to explore it further, would raise many points, some of which would be of more than a little difficulty. Nothing which I shall say, therefore, must be regarded as suggesting the slightest departure from the existing qualifications or practice of the Institution.

What I have in mind is, perhaps, not altogether unlike the general American degree of Master, obtained on a course of study which includes a substantial element of experimental work, but, in our case at any rate, not necessarily research. But, just as the Master's degree is awarded to those who have already an initial qualification, so should any special award of this Institution be restricted to those who have already been accepted as satisfying one of its own standards for admission.

Such a diploma, or whatever other title might be considered more appropriate, might exert a most beneficial influence in many directions. It would encourage an Associate, for instance, to continue his studies until, with the lapse of time, he may hope to qualify as a Fellow. It could hardly fail to raise the standards of attainment of those working in our industries. It might well provide an additional incentive to the provision of courses of still higher standard in the best of our colleges of technology and, for those engaged in industry, to undertake in them, in the evenings, work of a research nature.

When this should be done; what are the branches of metallurgy which might be distinguished by such an award; and under what conditions such awards should be made, are questions regarding my own views on which I refuse to offer any observations here. The President of this Institution is merely at the tiller, it is for the members, through the Council, to decide the course.

Sooner or later, this Institution must seek its own charter and when this is to be will demand careful consideration. When the time is ripe, and perhaps even before this, the question of a coat of arms, more in keeping with the dignity of the Institution, ought not to be overlooked.

INSTITUTION OF ELECTRICAL ENGINEERS

Annual Report

The Council's report for the year ended March 31, 1955, was presented to the Institution of Electrical Engineers at the annual general meeting on Thursday, May 19.

The membership at the date of the report was 39,928, an increase of 802 over the figure of a year previously. This was larger than in each of the preceding three years but is considered to be insufficient in view of the national need for qualified electrical engineers. The Council therefore gave much attention to the problem of recruitment. Among the measures that were put in hand was an analysis of the extent to which places available in the electrical engineering departments of universities were being filled, participation in careers exhibitions and the preparation of a booklet dealing with a wide range of engineering activities. A separate, though associated problem which was actively studied was why so high a proportion of young men who have decided to make electrical engineering their career do not join the Institution at an early age.

In view of the current shortage of text-books a Technical Publications Panel was formed to encourage publications, especially works of post-graduate standard. The education of engineers in the colonial territories was the subject of representations to the Secretary of State, who confirmed that he would encourage the provision of faculties of engineering science. Detailed syllabuses for the first three-year course and for the second and specialised part of a five-year course for electrical technicians received the attention of the City and Guilds of London Institute.

The report covers in detail with the other activities of the Institution and gives summarised accounts of the various technical investigations with which members are associated either alone or jointly with other bodies.

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POWER FOR ALUMINIUM PRODUCTION

Film of Kemano-Kitimat Hydro-Electric Scheme

To extract one ton of aluminium from bauxite ore requires 20,000 kilowatt-hours of electrical energy; it follows that the economic production of aluminium in quantity depends on the existence of vast power resources. To generate electricity for this purpose, the Aluminum Company of Canada conceived and carried through their immense Kemano-Kitimat project in the mountain wilderness of central British Columbia, and the whole course of the work has been recorded in a colour film entitled "The Kitimat Story."

The complete scheme, which was described in ENGINEERING (vol. 177, page 430 and vol. 178, pages 199 and 221, 1954), comprised five main engineering operations: the building of a dam to impound a chain of lakes; the driving of a ten-mile tunnel through the mountains to give passage to the falling waters; the excavation of an underground granite cavern at Kemano to accommodate the power house; the erection of a power line from Kemano to Kitimat; and the construction of the aluminium-smelting plant at Kitimat. Each stage is vividly depicted in the film against a background of magnificent mountain scenery, and other aspects of the work covered include the use made of helicopters and the construction of a new town near the site of the smelting plant.

The film runs for approximately 35 minutes and is on 16-mm. gauge. Further details may be obtained from Mr. Leslie Calver, Aluminium Union Limited, The Adelphi, John Adam-street, London, W.C.2.

THE LITERATURE OF CONTROL ENGINEERING

*By R. H. Macmillan**

Until about four years ago, we could expect a worthwhile book on automatic control or servomechanisms to appear in English every year or so, and a major international conference would be called perhaps once in five years. But interest in this branch of engineering has developed so rapidly that the conferences have become annual events and important new books on control or related topics are now published every month. There are also several new periodicals devoted largely to material likely to interest the control engineer, in addition to an increased output of such papers by the established engineering journals.

Though this rapid accumulation of published literature is typical of many branches of engineering, it is doubtful if any other one has exceeded it. Firms and institutions wishing to build up a small library in the field may therefore be glad of a brief guide to some of those parts of the mass of material now available which are likely to prove most useful to them. In view of the fact that a recently published bibliography lists no less than 94 books on automatic control, 106 books on computation and cybernetics, 44 journals and eight bibliographies, the remarks that follow are limited to publications in English (except where there is no equivalent available), but even so, only a selection can be given.

The classic work by Brown and Campbell[1] on servomechanisms has now been largely superseded by more comprehensive texts along the same lines, such as those of Ahrendt and Taplin,[2] which includes a discussion of relay systems, and Thaler and Brown,[3] which also treats the roots locus. The emphasis of the latter is more on electrical control than is that of the former. All of these books employ the notation of the Laplace Transformation; books requiring less mathematical knowledge are those of Lauer, Lesnick and Matson,[4] which is purely introductory, and Trimmer,[5] a most admirable analysis of the fundamental principles of the behaviour of physical systems.

Porter's monograph[6] and West's text[7] are good introductions for the electrical engineer, and Tustin's book[8] is a readable account of the electrical machines used in control applications, as is also that of Adkins, Whiteley and others.[9] The best account in English of process control theory is by Farrington,[10] but much preferable is Oppelt's work,[11] which is a development of his two previous volumes: it treats process control by the frequency-response method, but is unfortunately not yet available in translation. The books by Eckman[13] and Smith[14] in this field are now becoming distinctly out of date. The book by Macmillan[14] aims to introduce the principles underlying the analysis both of process controls and of servomechanisms.

A number of books are on a more advanced plane, either because of the mathematical techniques used or because of the matters treated. An early one is by MacColl,[15] highly condensed and still valuable, and another is the classic in the Radiation Laboratory Series by James, Nichols and Phillips.[16] Recently, two further valuable books have reached us: those by Truxal[17] and Tsien,[18] which are reviewed elsewhere in this issue. Flugge-Lotz's book[19] is devoted to the treatment of relay control systems by phase-plane methods, and Evans[20] has used his root locus method to great effect throughout his text. One of the most useful advanced works is the collected papers and discussions contributed to the Cranfield Conference in 1951.[21] The proceedings of a symposium held in 1953,[22] give a broad picture of much of the work then completed on non-linear control problems.

Control engineers must also have some acquaintance with automatic computers. Crank's little book[23] is a good introduction to analogue machines, and that edited by Bowden[24] is a very readable account of the construction and possibilities of digital machines. Olson's[25] book is also of interest in this connection. On the wider aspects of control theory, or cybernetics, and related topics, the following books are worth attention: Wiener's latest,[26] dealing with the social implications; Diebold,[27] on the automatic factory, and Woollard's more technical account,[28] with a chapter on the same subject; Bell[29] on information theory; and Tustin[30] on feedback in the economic system. There are also several new books on the theory of games, such as McKinsey's,[31] which are somewhat easier to read than Von Neumann and Morgenstern's great treatise.[32]

Those established journals which most often publish matter of interest to the control engineer include the *Proceedings* of the Institution of Electrical Engineers, the *Transactions* both of the American Institute of Electrical Engineers (*Applications and Industry*) and of the American Society of Mechanical Engineers; particularly valuable are the issues of the second dated November, 1953, and of the last for November, 1954, which contains the complete proceedings of the Frequency Response Symposium held in New York in December, 1953. Comparative newcomers are the *Transactions* of the Society of Instrument Technology, now appearing in an improved format, and the *I.S.A. Journal*, its American counterpart. Recent ventures of considerable interest are *Control Engineering*, *Automation*, and *Regelungstechnik*. Many valuable papers on automatic control are published in the *R. and M.* series of the Aeronautical Research Council and as *Reports* of its American equivalent, the National Advisory Committee for Aeronautics. A number of periodicals published by individual instrument firms have most valuable features: *Instrument Engineer*, for example, includes a useful bibliography of current literature. The three most extensive and conveniently available bibliographies of the literature are those of the Ministry of Supply,[33] Fuchs[34] and the American Institute of Electrical Engineers.[35]

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BOOK REVIEWS

Engineering Cybernetics. By H. S. TSIEN. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (6·50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (46*s.* 6*d.*)

Automatic Feedback Control System Synthesis. By JOHN G. TRUXAL. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (12·50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (89*s.* 6*d.*)

A great many papers of interest to the research worker in automatic control and servomechanism have appeared during the last five years, but until now there had been no advanced text-book which dealt with several of the most recent

topics. The publication of these two volumes is therefore most opportune: they are complementary to each other, for the approach and the ground they cover are in many respects markedly different. Dr. Tsien, of the California Institute of Technology, has been working in the aeronautical field, particularly jet propulsion, whereas Professor Truxal, now at the Polytechnic Institute of Brooklyn and formerly of the M.I.T. Research Laboratory of Electronics, is primarily an electrical engineer. Neither book shirks the mathematical difficulties which are involved but the background assumed should be available to any graduate worker in the field.

Dr. Tsien devotes his first 40 pages to a revision of the frequency-response approach and of elementary transient analysis; this is done with a brevity made possible by the concise style and notation adopted throughout. The next ten pages introduce the root locus approach and include a brief note on multiple-loop systems. Chapter 5, which follows, is devoted to the analysis of multi-variable systems without interaction; as with several other sections, this one makes available for the first time in book form work published in N.A.C.A. Technical Reports. The treatments of alternating-current servos and of sampling servos follow the methods given by MacColl*; for the latter however, simpler and more powerful techniques are now available. To analyse systems with finite time delay, Satche's illuminating modification of the Nyquist diagram is described. The statistical approach to design is introduced in 25 pages. Relay and non-linear systems are given a rather superficial treatment; particularly inadequate is the discussion of the describing function method. An interesting chapter uses the perturbation theory approach to the analysis of linear systems with variable coefficients. Non-linear design for specified optimal criteria is next discussed and statistical methods applied to minimising the error in the presence of random noise. The last two chapters are unusual: one deals with Ashby's work on ultrastability and the " Homeostat "; the other treats von Neumann's theory of multiplexing, as expounded in his lectures " The Synthesis of Reliable Organisms from Unreliable Components."

Professor Truxal ranges less widely than Dr. Tsien over the whole field but, in a book of more than twice the length and nearly double the price, he covers his chosen ground in an extraordinarily thorough and satisfactory manner. The narrowing of scope has permitted the production of a closely integrated account. The first chapter is a mathematical introduction which gives a useful description of the relevant complex variable theory, partial fraction expansions and Laplace transform theory. The next two chapters are devoted to basic filter and circuit theory. The use of " signal flow " (or, as they are often called, " dependence ") diagrams, as an alternative to block diagrams, leads to the concept of " return difference," which is a quantitative measure of feedback, and simplifies the stability analysis of multiple-loop systems. The methods of network synthesis to obtain a desired transmittance are then discussed at length.

The following three chapters treat design in the " s-plane " (s being the Laplace complex variable); it includes the root locus and phase loci approach, Guillemin's work on pole-zero configurations and the treatment of multiple-loop and alternating-current systems. The next pair of chapters cover the statistical approach to design; an unusual feature here is the use made of the two-sided Laplace transformation. Minimisation of error in the presence of a constraint, by introducing a Lagrange multiplier, is discussed, and reference is made to the treatment of non-linear systems and non-stationary time series. The remaining three chapters are devoted to non-linear control and constitute the most useful connected account of this topic which has yet appeared for the servo engineer. The first of them, on sampling systems, is a masterly exposition of the relation between the various current developments. The next one gives an admirable review of the describing function method, pointing out that its essential feature is the fact that it enables rapidly moving poles and zeros to be replaced by slowly varying critical frequencies. While this method enables us to examine the effect of harmonic inputs to a non-linear system, the effect of step inputs can be examined by the phase-plane approach, as in the final chapter, where the determination of optimum switching criteria is also treated. The frequent sections of discussion throughout the book are very lucid and constitute a most valuable feature.

Truxal's book would be a good successor to the one by Thaler and Brown,* for example, while that of Tsien, with its more condensed style and less electrical viewpoint, is more nearly in the line of Macmillan's.* It will be useful to anyone wishing to obtain a broad view of the field, while Truxal's is suitable for someone needing enough information to embark on design or desiring a thorough understanding of any one of several aspects of advanced servo theory.

* Reference is made to these books in the article on Control Engineering Literature in this issue.

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A FACTORY REBUILT

Schiess of Düsseldorf

During a recent trip to Germany a visit was made to the factory of Schiess A.G. at Düsseldorf-Oberkassel. This factory was bombed during the war and dismantled afterwards. When it was possible to start rebuilding, it was also possible to plan a completely new factory in the design best suited for production. By the kindness of Dr. Arthur Grund and the Chief Engineer, Herr Wallrodt, a detailed tour was made of the main shop, and the results of this planning were evident.

The company began building machine tools in 1869, and acquired an international reputation for heavy machine tools with electric drive. By choosing Düsseldorf as the site for their factory, with its excellent transport facilities and swiftly developing industrial importance, the originators of the company laid a foundation which the devastation of the second world war failed to shake. Although the factory was in ruins, the reputation remained. In 1948 the labour strength was about 900, much the same as it had been in 1900. For the next four years, until 1952, building was continuous. Herr Wallrodt was able to design the factory in the most convenient possible form, and flow lines which had previously been dreams were at last realised. A tour round the works shows how well the component parts of the factory have been placed in relation to each other, and the speed of production shows how well the system works.

All material is brought by rail, since the factory is just too far away from the Rhine to make the building of a canal economic. The raw material is cut up and treated in any way that is required, or passed directly to the casting shop. Pinions and gear wheels when cut are returned to the treatment room for hardening, and in the main hall the final products are assembled. Without detailed drawings of the paths of the units in any assembly, it is difficult to appreciate the fine planning of the machine-tool building, but the order and lack of confusion are immediately apparent to the visitor. The general cleanliness of the areas between the shops of the factories was more like the well-kept garden of a hospital than the area which in so many factories is used for storage of odd piles of rusting semi-scrap.

The results of this organisation are that the sales of the company rose from 11 million D.M. in 1949 to 55 million D.M. in 1952. Since 1952 the company's profits have risen to much higher levels, although exact figures are not available. In 1952, the company began to take their employees into partnership. Under this system the employees receive the same share of the profits as the stockholders do. For the stockholders, the share is paid in the form of a dividend on capital, while the employees receive it on their annual wage. As well as this additional percentage, they also receive Christmas bonuses.

As pointed out in a Weekly Survey note in this issue, the German recovery owes much to the planning and hard work of the engineers and the directors of industry; probably it owes more to their hard work than to that of the industrial rank and file. By encouraging their workers to work hard, and by arranging their factories so that hard work by the individual has the maximum effect on output, German industrialists have shown a tremendous rise in production from their factories. The virtual destruction of much of their pre-war industrial plant has been a blessing in disguise.

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Obituary

MR. H. GRINSTED, C.B.E.

Aeronautical Development

We learnt with regret of the death, which occurred on Saturday, May 21, at Shackleford, Surrey, of Mr. H. Grinsted, C.B.E., B.Sc., F.C.G.I., F.R.Ae.S., former Director of Aircraft Research and Development at the Ministry of Supply.

Harold Grinsted was born on March 14, 1889, and received his technical education at the City and Guilds College, London, graduating with first-class honours in 1909, after which he was apprenticed, as a Senior Scholarship pupil, with the Daimler Motor Company. He joined the Royal Aircraft Establishment in 1912 as a draughtsman and subsequently held positions there as head of the stress office, head of the physics and instruments department, chief engineer of design, and finally superintendent of technical development.

He was transferred from Farnborough to the Air Ministry in London in 1931, as assistant director of aircraft research and development. During the second World War he served as deputy director of research, development and technical investigations at the Ministry of Aircraft Production. When the Ministry was disbanded in 1946, he was transferred to the Ministry of Supply where he served as director of aircraft research and development until he retired in 1950.

Mr. Grinsted was awarded the O.B.E. in 1918 and the C.B.E. in 1946. He was elected a Fellow of the Royal Aeronautical Society in 1941 and, in 1953, was awarded the Society's Silver Medal for outstanding work in aeronautical engineering. On May 5 this year he was made an Honorary Fellow of the Society. He was elected a Fellow of the City and Guilds Institute in 1950.

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We also regret to record the deaths of :

MR. GEOFFREY FERDINAND FALK, which occurred in London on May 24 at the age of 56. He received his technical education at Faraday House and with the General Electric Co., and then joined the family firm of Falk, Stadelmann and Co. He eventually became responsible for the factory making heating and cooking apparatus and more recently was a director. During both the 1914-18 and 1939-45 wars he served in the Royal Corps of Signals, his last appointment being Deputy Chief Signal Officer, South Eastern Command. He was elected an Associate Member of the Institution of Electrical Engineers in 1931, becoming a Member in 1943. He was the holder of the Territorial Decoration.

MR. WALTER LUDOW TAYLOR, at his home in Bedford, on May 18. Mr. Taylor was sales supervisor of B.E.N. Patents Ltd., High Wycombe, Buckinghamshire, and had been 18 years in the service of the company.

MR. ALBERT EDWARD BONE, of Benton, Newcastle-upon-Tyne, on May 24, at the age of 64. He was a director of Watson-Norie Ltd., electrical and mechanical engineers, Newcastle. Mr. Bone joined the firm 38 years ago.

BOOKS RECEIVED

Some of the books noticed here are selected for extended review in later issues of ENGINEERING.

Radar and Electronic Navigation. By G. J. SONNENBERG. Second edition. *George Newnes, Limited, Tower House, Southampton-street, London, W.C.2.* (31*s.* 6*d.*)

This book, intended for merchant ships' masters and navigating officers, deals with the practical aspects of operation of the Decca, Loran and Consol systems, radar and echo sounding. In the second edition a new chapter on direction finders has been added, and the chapters on the Decca system and radar have been expanded.

Theoretical Structural Metallurgy. By A. H. COTTRELL. Second edition. *Edward Arnold (Publishers), Limited, 41 Maddox-street, London, W.1.* (25*s.*)

Dr. Cottrell is Professor of Physical Metallurgy in the University of Birmingham and the aim of his book is to show metallurgical students of all ages how modern atomic mechanics can be applied to problems of metals and alloys and to the fundamentals of physical metallurgy. His opening chapters deal with the structure of the atom and forces between atoms. He then discusses the free electron theory and its applications and goes on to treat such matters as the free energy of alloy phases, the equilibrium diagram diffusion in metals and alloys, the order-disorder change and the kinetics of phase changes. His final chapter describes shear processes in metal crystals. The theoretical outlook has been adopted throughout and experimental methods are not discussed.

Servomechanism Practice. By WILLIAM R. AHRENDT. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (7 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (50*s.*)

This book describes mainly the practical aspects of servomechanisms. The theory is outlined, and is followed by discussions of circuitry, electrical and mechanical components and recent advances in their performance and utilisation. It describes practical problems and procedure in servomechanism design and manufacture. The book is written for the student, executive, and design engineer.

Plastics Engineering Handbook. Official Handbook of the Society of the Plastics Industry, Incorporated. Second edition. *Reinhold Publishing Corporation, 430 Park-avenue, New York 22, N.Y., U.S.A.* (15 dols.); and *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (120*s.*)

The second edition of the S.P.I. handbook is divided into five major sections: materials and processes, design, finishing and assembly, testing, and S.P.I. standards. All chapters have been either rewritten or written for the first time to describe new techniques or developments. The book is for members of the plastics industry, material suppliers, designers, fabricators, finishers or users of plastics, and is particularly useful as a work of reference.

Metal Industry Handbook and Directory, 1955. Published for "Metal Industry" by *The Louis Cassier Company, Limited, Dorset House, Stamford-street, London, S.E.1.* (15*s.*)

The 44th edition of this handbook contains up-to-date information on the properties of the newer as well as the more familiar metals, and an extensive section is devoted to summaries of British Standard, Aircraft Material, D.T.D. and Admiralty specifications. Sections are also included on the chief metal-finishing processes and data regarding all the common rod, bar, sheet and strip products. Two new features included in this edition are standard classifications of non-ferrous scrap, and a list of trade names.

Oxford Junior Encyclopaedia. Vol. VIII: Engineering. Edited by LAURA E. SALT and ROBERT SINCLAIR. *Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4.* (30*s.*) (Reviewed on page 656 in the issue of May 27.)

British Plastics Year Book, 1955: A Classified Guide to the Plastics Industry. 25th edition. *Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1.* (30*s.*)

The sections classified in this book include: patents and new companies registered in 1954; plastics specifications, material suppliers, product manufacturers and processers; directory of trade names, technical terms, firms, organisations, consultants, and trade associations; technical and general data and an index.

Institution of Naval Architects Spring Meeting (*concluded from page* 661)

CATHODIC PROTECTION OF SHIPS

EXPERIENCE WITH LAID-UP SHIPS OF RESERVE FLEET

The final session of the 1955 Spring Meeting of the Institution of Naval Architects was held in the Weir Hall of the Institution in the afternoon of Wednesday, April 6, when Mr. L. T. Carter, B.Sc., R.C.N.C., and Mr. J. T. Crennell, M.A., jointly presented a paper on "The Cathodic Protection of Ships against Sea-Water Corrosion." The chairman at the meeting was Mr. Norman M. Hunter, Vice-Chairman of the Council.

The authors defined cathodic protection as "the prevention of corrosion by the passage of a sufficient electric current through an electrolyte to the surface of the metal, in the direction which makes the metal a cathode," and explained that the functions of cathodic protection and protective coatings were complementary rather than competitive; a judicious combination of the two was the best practice. The method of applying cathodic protection to a ship's hull was by passing current to the hull by external anodes, the current being obtained either by using active anodes of a baser metal or from an external supply through inert anodes. The anodes most commonly used were of magnesium alloy and steel, respectively. The adequacy of the protection could be guaranteed if the electric potential of the hull was maintained, by adjustment of the current, at about 0·8 to 0·9 v. negative to a standard silver electrode. Zinc has fallen into disrepute as an anode material because of the inactivity of zinc protectors, the surface of which became coated with a highly resistant crust of corrosion products; but recent work suggested that this disability might be overcome, in which case zinc anodes would have advantages in certain applications. Their particular value lay in the fact that the potential of zinc was only slightly above the protected potential of a steel hull, so that they required little maintenance and involved little danger of paint stripping.

Mr. Carter, who presented the paper, and who is Assistant Director of Naval Construction Admiralty, went on to say that the Admiralty had had encouraging results in the application of cathodic protection to laid-up ships of the Reserve Fleet. The protection was given either by the use of an impressed current, when ships were berthed in groups alongside jetties where shore current was available, or by magnesium anodes when ships were berthed singly at buoys or when current was not available. The approximate installation costs for a minesweeper with a wetted surface of about 7,500 square feet were £156 for magnesium anodes and £160 when using impressed current. Cathodic protection had not been adopted yet for operational ships, which presented different problems. In such cases, the anodes must be fixed to the hull and not suspended overboard, as was done with moored ships; and when under way a ship required more current than when at rest, so that variation of the current was necessary to avoid over-protection, with consequent damage to paint coatings, when the ship was stationary. It was believed, however, that as the possibility of preventing corrosion of iron and steel in sea water by cathodic protection became more widely known, the method would be more generally used for the protection of other metal structures immersed in sea water.

DISCUSSION: ZINC PROTECTORS

Mr. W. A. D. Forbes, opening the discussion, said that, as a former chairman of the Admiralty Corrosion Committee, it gave him particular pleasure that recent work of the Committee should have resulted in the production of a paper of such value and importance. Over the past 10 or 12 years, the Committee had done a great deal of work on the maintenance of ships and had saved the Admiralty, and thus the general taxpayer, a great deal of money. He thought that it would greatly benefit the shipping industry if the Institution gave more encouragement to papers on ship maintenance. Much attention had been paid to theoretical subjects and problems of resistance and propulsion, but the diversion of some of the money and effort to problems of ship maintenance might produce even better results for the shipping industry. What was the purpose of straining after the last fraction of a knot and neglecting the fact that barnacles on the bottom might well reduce the speed by several knots, and vastly increase fuel consumption, however the ships might be streamlined.

The authors had shown conclusively that it was possible to protect from corrosion the hull of a laid-up ship or a floating dock almost indefinitely by methods which were simple, practical and cheap, and which were also applicable to the fitting-out period, often a fruitful source of trouble. He doubted, however, whether the last had been seen of zinc protectors, if improved forms become available. Many shipyard workers regarded zinc protectors as a troublesome nuisance, needing constant renewal, and felt pleased when they were found inactive and apparently requiring no attention. Since their purpose was so little understood, it was hardly surprising that they so often received unfair treatment. Not infrequently they were painted over and given no chance to act, and often it was not realised that it was essential that the zincs should be in really good electrical contact with the steel hull. He recalled one instance in which the zincs were loosely enclosed in a cage welded to the rudder, and the only purpose served was to create unnecessary eddying. Apparently, the main idea was not to lose the zincs.

WET SANDBLASTING

Wet sandblasting, which had been mentioned by the authors, was not popular in the dockyards. Possibly it was considered to be merely a fad of the Corrosion Committee; but he would continue to advocate replacing manpower by machine power for hard and dirty jobs. The attitude to that problem in the United States was completely different. For many years, wet sandblasting had been in universal use in United States Navy yards, and it proved invaluable during the war. The equipment was also used by the Canadian and Australian navies and apparently no difficulties arose from silicosis. During the war in the Pacific, the use of that equipment, together with hot plastic anti-fouling paints, enabled ships of the U.S. Navy to remain out of dock, and operationally available, for periods far in excess of anything known by British standards. Had the war in the Pacific continued a few months longer, the inadequacies of the British Navy in that respect would, he thought, have been glaringly apparent. It is a pity that, ten years after the war, there was still no dock in the United Kingdom in which the hull of a ship could be cleaned to bare metal rapidly and the ship restored quickly to operative duties. The special feature of importance about wet sandblasting was that it was a time and labour saver; and time and labour were both scarce commodities in war time. It was a modern mechanised method of doing a hard and dirty job effectively, and means of overcoming the handicap of labour shortage and inefficient labour. With such equipment the hull of a ship could be cleaned to bare metal quickly, using a small labour force; without it, the job could not be done at all, unless a very large labour force was available for a long time and was rigorously supervised.

CATHODIC PROTECTION AND PAINT

Dr. U. R. Evans welcomed the paper from the points of view of cathodic protection and the information it gave about paints. The points which interested him most were those concerning the protection of the wind and water-line zone on ships of the Reserve Fleet, because a cementiferous paint was used, covered with two coats of chlorinated rubber-based paints. So far as could be seen, the results were satisfactory, because two ships, which had been inspected after two years, were showing good behaviour at that zone; he thought it unwise to boast too soon. He was puzzled by the choice of the cementiferous paint used. The idea in using such paints was to protect the steel against corrosion; he gave no thought, at first, to avoiding attack by alkalies. In fact, the E.412 paint appeared to be about the best from the anti-corrosion point of view, but he would not expect it to be the best from the point of view of resisting alkali because it contained zinc oxide, which was well known to be dissolved by alkali to some extent. Some of the other cementiferous paints contained no zinc oxide. Presumably, at the wind and water line it was necessary to consider two periods, the wind period and the water period. During the water period there was cathodic protection, and danger of alkali formation. During the wind period there was no cathodic protection and, consequently, a paint was required which was protective against corrosion. Presumably those who had to make the choice, having to make a bargain, chose a paint which was protective against corrosion and not so resistant to alkalies. He would be interested to know whether that was the argument put forward. It was not just an academic matter; it had importance at other parts of a ship, apart from the wind and water line. The only way to ensure that good behaviour from the paint over the whole of a ship was to have a system which was proof against alkaline softening and alkaline peeling.

Some years ago there was a commercial paint recommended by marine consulting engineers which did extremely well in marine situations generally, but now and again it would peel off quite large areas. It was studied, with many other paints, in a research which he had published in the *Journal of the Chemical Society* in 1929. Hardly any work on the subject seemed to have been done since then, though it was one of very great importance. He offered a suggestion which might be worth considering as a means of overcoming that trouble. One might first apply one of the cementiferous paints which was more resistant to alkali and had less anti-corrosive properties; the anti-corrosive properties would not be needed if that part of the ship was to receive cathodic protection. If a paint could be found which was sufficiently resistant to alkali, the application of outer sealing coats of an organic character would probably be effective, because they were not likely to peel off, but would sink into the cementiferous coat, which was quite porous, so that there would be at least a chance of achieving good adhesion.

Mr. K. A. Spencer thought that the paper was probably the best yet published on its subject in Great Britain; he had gained much useful information from it. On the question of cathodic protection in fresh water, he had seen quite extensive corrosion under such conditions, and, of course, fresh water tanks were frequently cathodically protected internally; so he did not think it should be discounted too much for such conditions.

PROTECTION OF PROPELLERS

Mr. W. G. Waite, commenting on the authors' reference to the wastage experienced on ships' propellers, said that there appeared to be a general impression that the so-called cavitation erosion resulted from an action which was unusual in that it was mechanical. He could offer evidence to show, however, that it could be prevented by cathodic protection.

With regard to the method of rigging steel anodes shown in the paper, he would have thought that the suspension illustrated would have failed in a comparatively short time, with the loss of the anodes themselves. Evidently he was wrong, as the authors had used it for at least a year; but he would like to know what was the appearance of the anodes when they were taken out of the water, and whether they attained the 75 per cent. efficiency of consumption indicated in the paper. He suggested that advantage could be taken of interference effects to lessen the possibility of losing metal at the welded joints.

Mr. A. J. Sims inquired whether the electrode described in Appendix I was capable of producing a potential survey over the hull as a whole, as he felt that different sections, probably of slightly different compositions or subjected to different treatments in manufacture, tended to produce inter-chemical activity. If the reference electrode referred to was capable of producing a potential curve for the hull as a whole, what sort of difference of potential was measured in different parts of a ship's structure? The paper stated that a ship under way required 50 per cent. more current than when moored in a tideway, and presumably required three times as much current as when she was in a non-tidal basin. It would be interesting to know when the increase occurred and whether the requirements remained more or less stationary over a fair zone of the ship's speed. Did the current required between speeds of 15 and 30 knots remain fairly stationary, or did it vary a lot with increase of the ship's speed?

Dr. W. F. Higgins said that the research associations had investigated factors influencing the life of cast-iron propellers, and he referred to the deterioration of cast-iron propellers in merchant ships, which he called pitting attack. He was not prepared to discuss whether the attack was bound up with mechanical effects, or with cavitation; but he claimed that that particular form of deterioration could, under suitable conditions, be completely prevented by an adequate degree of cathodic protection.

USE FOR STRUCTURES AS WELL AS SHIPS

Mr. G. A. Bassett asked whether the current was limited to the extent of not producing hydrogen, in which case it would not produce the marbling effect which protected the steel structure. Undoubtedly, there was a great future for cathodic protection, not only for ships which were laid up, but for any structures fixed in the earth, including some of the new docks being built, as well as piles. British practice was not so backward in respect of sandblasting as some people thought. More than 20 years ago, sandblasting was tried in this country on a ship, in a dockyard. As recently as two years ago, attempts were made to get shipbuilders to accept sandblasting for some ships, but it was turned down. The fault lay in the system which enabled regulations to be applied which prevented the use of the method unless many people were employed. In both France and Italy, some ships had been sandblasted.

The Chairman (Mr. Norman Hunter) inquired whether anybody had tried the latest burning method. It would save all the tons of sand, and the labour required to deal with it.

Mr. M. Varvill, referring to the section of the paper dealing with the protection of sheet-steel piling in jetties, where the area to be protected varied according to the state of the tide, quoted the authors' remark on the difficulties of controlling the current in such conditions. Generally speaking, in harbour or estuarial conditions it was automatic; at high tide the salinity of the water was at its greatest, and its resistivity was considerably reduced.

EFFECT ON FOULING

Mr. J. H. K. Tait asked whether the authors would comment further on their suggestion that a small magnesium anode had a lower efficiency than a larger one. They had referred also to the effect of cathodic protection on the fouling of a hull, and appeared to be in doubt whether there was any effect on the fouling. He thought that doubt was very general. In his own experience, two reports came from Australia, stating that two cathodically-protected ships were fouling in a perfectly normal manner. Just as it seemed that the problem would be solved on a statistical basis, there was a reversal of that view; yet the last half-dozen cathodically-protected ships in United Kingdom waters to be inspected had shown little or no fouling. Any information that the authors might care to publish on their experiments would be greatly appreciated.

It was stated in the paper that, when under way, the ship required more current for cathodic protection than when at rest, and variation of current was therefore necessary to avoid over-protection (with consequent damage to the paint coatings) when the ship was stationary. The second of those requirements, the authors stated, clearly favoured the use of an impressed current system. He had observed in the engine room of the ship mentioned in the paper, that when the ship was under way the current went up automatically. A certain amount of automatic effect was of great advantage, particularly in a merchant ship. He invited the authors to comment on their point that the second requirement favoured the use of an impressed current system.

In the paper, they considered the application of cathodic protection during fitting out, and remarked that the points to be considered when deciding to apply cathodic protection were that the ship might be moved to different berths; that the draught and wetted area, and consequently the current demand would increase, and that other ships alongside would steal some of the protective current. These points were not the only ones to be considered; there were many others, such as welding operations, carried out more or less continuously during fitting-out; also, most yards were up rivers, and the salinity of the water varied with the tide and the season. It was also stated that, so far, cathodic protection had not been widely adopted in Britain for the external protection of hull plating of merchant ships. That was true, but there was some experience of it, all of it good. Recently a 17-knot cargo liner came in after seven months; there was no corrosion below the waterline, and no fouling.

Mr. A. J. Merrington, C.B.E., said that the authors, in referring to cathodic protection applied to the internal compartments of a ship, pointed out the limitation of the magnesium anodes and rather suggested that zinc anodes offered were best in that connection. The Admiralty had recently investigated the general hull maintenance of the Fleet and had examined more than 100 hull inspection reports, for frigates and cruisers, and had made a simple and rough classification of them. The analysis showed that the black spots were in the lower deck, forward and aft, which were three or four times as bad as the outer bottom plating near the fuel tanks. The lower deck fore and aft in those small ships was subject to alternate wetting and drying. He asked whether the authors saw any possibility of dealing with that problem in the light-scantling ships by cathodic protection.

Mr. P. V. Palmer said that he had some figures concerning protection in fresh water relating to the protection of a water structure when the resistivity of the water was varying from some 30 ohm-centimetres to about 1,000 ohm. cm., and offered to communicate them so that the authors could comment.

DUTCH EXPERIMENTS

Mr. A. P. Cole, M.B.E., said that, while the authors had referred to developments in America and Canada, they had omitted any reference to the very important experiments carried out by the Dutch. They had marketed cathodic protection under a registered name and had fitted it externally in one of their ships, on the bilge keels. The ship was at present on a voyage to the Far East and would be back in six months. In the protection of piling, they had found copper anodes most effective in removing marine growths. The Dutch had found that, in addition

to the cathodic coating which the authors mentioned in the paper, there was an electrochemical change in the electrolyte. In connection with ships' circulating water, such as in sanitary systems, Diesel machinery, etc., the method was to put the anodes in a reaction tank in the circuit, and generally it was found that aluminium anodes were by far the best. He could not explain what they did, but in one Canadian merchant ship very good results were obtained and the shipowners had specified the system for all their ships. A Canadian frigate had trouble with Diesel machinery, where there was intense corrosion of cylinder liners and heavy scale deposit. The system was fitted, with iron anodes, and lessened the scale. One of the liners cracked; it was replaced and aluminium anodes fitted in the circuit. That was five years ago. A recent report showed that it was satisfactory and the ship was still in service.

ANODE MATERIAL AND POSITION

Mr. J. H. Morgan said, with regard to graphite anodes, that the graphite was consumed at approximately one-fifteenth of the rate of steel; so that the surface-area effect was not the one which entirely controlled the resistance of the anode, because a low resistance could be maintained where the shape of the anode could be controlled. The usual shape for graphite was a long and thin rod, but that shape could not be used in steel because the corrosion was unpredictable and the anode might be lost straight away. In their diagram of a laid-up ship, the authors had suspended the anodes close to the ship. That was not necessary, and it would be of greater advantage if they had the anodes in a pack fill of something like coke breeze, some distance away; that would prevent channelling, and would be able to protect several ships.

Mr. J. H. Krietemeijer quoted the authors' statement on the removal of millscale from plates and sections, that it could be done by pickling and weathering. New methods are being developed on the Continent. In his own shipyard there was a machine which descaled plates and sections, not by sandblasting, but by steel-grit blasting, and the work was done fully automatically. A plate went through the machine at a speed of about 4 ft. per minute. It was not only the shipowners who wanted ships descaled; shipbuilders wanted it also, because derusting ships on the berths by means of brushes was a very dirty job. They intended to paint the sections as they came out of the welding shops, so that, when the ships were erected on the berths, they were fully painted except for the seams and butts, which had to be welded on the berth. They used a so-called welding primer with which they painted the whole sections, butts and seams as well; then they could weld over the paint.

ADVANTAGES OF FLAME-SCALING

Mr. John West said that in the case of a cargo ship about 500 ft. long, the cost of fitting sacrificial anodes to protect it was about £2,000. In addition, every 12 months there was an expenditure of about £1,000 for renewing the anodes, so that, in the life of the ship, the expenditure on its protection was roughly £25,000. Records showed that the expenditure on renewing shell plates for a ship was well below £25,000. On the average, the shell plates which were renewed most frequently were the keel plates, and he suggested that possibly the major reason was that they were so rarely painted. One of their rules was that, when they laid a new keel, the keel plates should first be painted; so that a keel plate, having been treated initially, should more or less last the life of the ship. They hoped that the repair bill for renewing keel plates would be practically nil. His personal experience, which was limited, was that flame scaling had one particular advantage which nothing else has: on Clydeside particularly rain fell fairly regularly, and they were able to apply the wash primer while the steel was still warm, so obtaining a very good bonding of the paint, which would stand up to wear and tear for a considerable period. He thought that was a great asset in flame scaling and went a long way to protect the hull, though he would not say that cathodic protection was unnecessary. He had compared two ships, one of which was cathodically protected and the other was not; both of them were flame-scaled. There was absolutely no difference between them when they were dry-docked after the short period of four months. The cathodic protection was not able to assist much, because the flame scaling and the application of the wash primer did all that was required.

AUTHORS' REPLIES

Mr. Crennell, in a brief reply to the discussion, said that several speakers had commented on points raised by others more effectively than the authors could have done. They did not want to say anything derogatory about the Admiralty anti-fouling paint; in reply to Dr. Evans, when they chose D.412, they definitely chose a good cementiferous paint and one which was inorganic. Cathodic protection in fresh water had been mentioned by one or two speakers, but there might be a difference of opinion about what was fresh water. One speaker mentioned a variation of resistance of from 30 to 1,000; fresh water was of much higher resistance than that. A difficulty was that if the near parts of the hull were protected with a few anodes, the remote parts of the hull would have a very different potential, and to protect them equally would involve a dangerously high potential at the near parts. Reference had been made to the corrosion of long steel rolled anodes; the fact was that the corrosion of a long steel rod occurred almost exclusively at the tip, due to geometrical factors. With regard to the self-correction of current in a ship in motion, it was to be expected that it would be a rise of current if there was very little resistance control inboard; in other words, if the total voltage available was near the required voltage.

The Dutch system of cathodic protection, referred to by Mr. Cole, so far as it concerned the external protection of a ship, did not differ essentially from systems with which the authors were familiar. As regards internal protection, particularly in fresh-water systems, they had no experience of it; but, in his own view, that was not cathodic protection at all. He understood that it was very effective. Possibly what was happening, if aluminium anodes were used, was that, aluminium being a well-known flocculating agent, it probably led to the formation of a loose removable deposit rather than the hard scale that normally came down from hard water.

Mr. Carter, who also replied said that Mr. Bassett had referred to a method of cathodic protection in which a very high current was used to put down a thick calcareous coating. It had not been much favoured in Great Britain; its obvious disadvantage was that it was very costly in current. Mr. Merrington had referred to the maintenance of the lower decks of ships. Mr. Carter did not think that cathodic protection could well be applied in such a case, because it did require contact with an electrolyte. He added that the remaining points in the discussion would be dealt with in writing.

This concluded the 1955 Spring Meeting except for the annual dinner of the Institution which, as previously recorded, was held in the evening of April 6.

Iron and Steel Institute Annual General Meeting (*continued from page* 661)

CREEP OF STEELS AND ALLOYS

EFFECT OF ALUMINIUM CONTENT, CASTING TECHNIQUE AND OTHER FACTORS

We continue our report of the recent two-day annual general meeting, in London, of the Iron and Steel Institute, by dealing with the proceedings on the morning of the second day, Thursday, April 28. This session was devoted to the presentation and joint discussion of four papers all dealing with some aspect of the subject of creep.

The chair was occupied by Mr. James Mitchell, C.B.E., a past-president of the Institute.

The first paper, on "Causes of Variable Creep Strength in Carbon Steel," was by Mr. W. E. Bardgett and Mr. M. G. Gemmill, of the United Steel Companies, Limited, Sheffield, and was presented by Mr. Bardgett. The authors stated that creep and allied tests had been made on samples of 58 basic open-hearth casts of carbon steel in which the aluminium additions ranged from 1 to 2½ lb. per ton. The steels were selected with the object of determining the causes of variation in their creep strength. The reaction of oxygen during steelmaking had been examined for ten casts in relation to aluminium recovery. It had been found that the soluble aluminium present in the steel was a paramount factor in the variable creep behaviour, but that the McQuaid-Ehn grain-size was also related to it. Further consideration of these features had led to the view that the creep resistance of any of the steels was correlated directly with the aluminium-nitride content, which, in turn, was related to the soluble-aluminium content and grain-size characteristics of the steel.

From a practical point of view it would appear that steels of good creep resistance could be obtained with aluminium additions of up to 1½ lb. per ton, provided that mould additions of aluminium were limited.

LONG-TIME TESTS ON CR, MO AND V STEELS

The second paper, by Mr. J. Glen, of the research department of Colvilles, Limited, Motherwell, gave "Some Additional Creep and Rupture Data on Molybdenum, Chromium-Molybdenum, and Molybdenum-Vanadium Steels." Mr. Glen said that long-time creep and rupture tests had been carried out on test pieces from about ten open-hearth casts of each of three types of steel, namely, 0·5 per cent. Mo; 0·8 per cent. Cr-0·5 per cent. Mo; and 0·5 per cent. Mo-0·25 per cent. V. From these data an estimate had been made of the creep and rupture strength of the materials for a life of 100,000 hours. The results had shown that the Mo-V steel had creep and rupture properties much superior to those of the other two steels.

The elongation, at fracture, of the rupture tests had been measured, and it was noted that, at any given temperature, the elongation at fracture first decreased with increasing time to fracture and then increased with still longer times. It was also noted that as the temperature of testing was reduced, a longer time was required to reach the minimum elongation and that the value of elongation at the minimum decreased with decreasing temperature. The elongation of the 0·5 per cent. Mo steel became very low with long times of testing, but the elongation of the Cr-Mo and Mo-V steels remained high even in periods approaching 100,000 hours.

The third paper was entitled "A Statistical Study of the Creep and Fatigue Properties of a Precision-Cast High-Temperature Alloy" and was by Mr. G. T. Harris and Mr. H. C. Child, of the research department of William Jessop and Sons, Limited, Sheffield. The authors stated that the average mechanical properties, at room temperature, the creep strength at 700-850 deg. C., and the fatigue strength at 700-870 deg. C., had been evaluated for precision-cast G.34, a cobalt-base alloy developed for gas-turbine rotor blades. The alloy had the following nominal percentage composition: C, 0·8; Mn, 1·0; Si, 0·5; Ni, 12; Co, 45·0; Cr, 20·0; V, 2·8; Mo, 2·0; Nb, 1·2; Fe, 15. Several dozen test bars had been cast, by the de Havilland

Aircraft Company, Limited, using the lost-wax process, and the investigation had been carried out on small creep specimens and hot fatigue specimens machined from the cast test bars. A quality-control study of the rupture strength of G.34 castings had shown that the precision-casting process could be used to give consistent properties in that no greater scatter in properties need be expected, from heat to heat, than within one heat.

The scatter of the 300-hour rupture strength and the endurance strength (40×10^6 reversals) at 750 deg. C., had been found to be $\pm$ 10 per cent., and $\pm$ 22 per cent. The practical implication of these results was that the average values of the high-temperature properties must be reduced by about 15 per cent. in the case of applications in which creep was the limiting factor and by about 30 per cent. where fatigue was of major importance.

For an alloy of this type, fatigue was probably of leading importance at temperatures up to about 800 deg. C., while creep was more important above this range. Accordingly, best use could be made of this cast material above 800 deg. C., and it was above this temperature that the properties became attractive, in comparison with existing wrought materials. At these higher temperatures, the scatter in properties was also smaller.

PREDICTING LONG-TIME CREEP FROM SHORT-TIME TESTS

The last of the four papers dealing with creep was by Mr. A. Graham and Mr. K. F. A. Walles, of the Ministry of Supply, National Gas Turbine Establishment, Farnborough, Hampshire; it was entitled "Relationships Between Long- and Short-Time Creep and Tensile Properties of a Commercial Alloy." The authors stated that the reasons for presenting the paper to metallurgists were that the specific problem considered was one often faced by them, namely, that of predicting long-time creep from short-time tests and that the material studied was the alloy Nimonic 80. It had been necessary, however, to go outside the normal field of metallurgical interest to find a satisfactory explanation of the results. Short-time creep tests, two forms of tension test, and creep-recovery tests had been conducted and the results compared with long-time creep data for the alloys, supplied by the Mond Nickel Company, Limited, and the National Physical Laboratory. The results had been used to guide the development of a theory of deformation, based upon the equation due to P. G. Nutting in America and the Boltzmann memory principle, which theory met a variety of requirements. Satisfactory relationships had been established among the various results and the long-time data. The work, therefore, favoured the view that there might be a much greater uniformity between the behaviours of different materials than was generally supposed.

Dr. J. O. Ward, who opened the discussion, said that research at Hadfields Limited had shown that for a variety of carburising and medium-carbon steels produced both in the basic open-hearth and the basic electric furnaces, a minimum content of about 0·015 per cent. of soluble aluminium was necessary to produce a satisfactory grain size, corresponding to Nos.7 to 8 on the A.S.T.M. scale. This appeared to confirm the findings of Messrs. Bardgett and Gemmill. Moreover, it was pleasing to have confirmation of the influence of aluminium nitride on grain-size control and these authors had made a material addition to existing knowledge on the creep properties of carbon steels.

Mr. Glen had, once again, made a unique contribution to knowledge on the creep behaviour of a low-alloy steel. In explaining the long-term observations, he had arrived at metallurgical concepts similar to those which they (at Hadfields) had postulated to explain the data accumulated from short-term investigations on rather more complex alloys. It seemed to them that the important fact emerging from this work was that the creep properties of a given alloy, at a certain temperature, depended on the deviation of its constitution from the equilibrium state appropriate to the temperature and stress conditions under examination.

It was of interest to note that there was a tendency for a 3 per cent. Cr-Mo-W-V steel, when it was normalised and tempered at 730 deg. C. to a guaranteed impact level of 40 ft. lb., to exhibit poorer short-term creep properties, namely, up to 1,000 hours, than the same material tempered at 685 deg. C. When, however, periods of over 10,000 hours were considered, the material tempered at 730 deg. C. was considerably superior to that tempered at 685 deg. C. This laid additional emphasis on the warning given by the author that short-term investigations might be most misleading when extrapolated to provide long-term data. Consequently, the investigation of new composition fields for long-term applications must remain a difficult and protracted task.

INVESTMENT CASTING

Turning, next, to the paper by Mr. Harris and Mr. Child. The process of investment casting has been widely used in the United States for the production of both moving and stator blades for jet engines, but, in this country, it has been confined essentially to the production of stator blades, because there had been a reluctance on the part of the designers to use cast moving components.

It would appear that, in the future, moving blades would have to withstand higher temperatures and stresses and, therefore, such alloys might well be virtually unmachinable and unforgeable. It seemed that the most suitable alternative method to machining from forged or extruded material, at the present time, was investment casting. The present contribution, therefore, was valuable and indicated that a considerable amount of investigation was desirable in this important field.

Work carried out in the Hadfield laboratories had shown that, in a very wide range of alloys, great improvements could be effected by very careful attention to the foundry technique, in such matters as the design of in-gates and of feeder heads, the casting temperature, the deoxidation practice, and the pouring speed. In particular, it was essential to continue these experiments beyond the point at which castings appeared to be sound radiographically. They had been able to effect considerable improvements in mechanical properties by such continued attention.

They confirmed the authors' experience of wide scatter from the miniature Wöhler fatigue-testing machine, which in their experience had occurred at speeds of the order of 10,000 r.p.m. and had been invariably associated with visible resonant vibration effects.

Mr. Graham and Mr. Walles had presented a paper which had far-reaching implications if the results were applicable to other alloys. Unfortunately, they had been unable, owing to time limitation, to examine their materials in the extensive manner required to test the validity of the authors' formula.

NUTTING LAW IMPROVED

Mr. B. B. Overy said that he was particularly interested in the way in which Mr. Graham and Mr. Walles had tried to improve upon the existing Nutting Law, which now seemed to have some fairly well-accepted advantages and disadvantages. The chief advantage of the Nutting Law, as it stood, was that it would fit the results of any test series which gave straight-line log-log graphs of stress versus time, strain versus time, or stress versus strain, that being a very common feature in some creep results. Furthermore, the Law bridged the gap between Hooke's Law and the laws of viscous flow. It should be noted, however, that in tests in which the Nutting Law had been verified, it had been usual to adopt some definite method of loading, such as constant stress, controlled strain rate, or controlled rate of application of the stress.

Mr. R. Wood said that at the Mond Nickel Company's laboratories they had followed the development of the methods of Mr. Graham and Mr. Walles of correlating short-time and long-time creep results with great interest, since they had done much work upon the Nimonic alloys. They felt that the author's work formed a great contribution to the derivation of practical methods of prediction of long-time creep behaviour from shorter-time data. They had found that for several of their creep curves for Nimonic 90 the discrepancy between calculated and experimental values of strain over time up to 1,800 hours did not exceed 7 per cent. of the experimental values. Their findings, however, indicated that the prediction by the authors' methods must be limited in scope.

Mr. J. Glen, the last speaker in the discussion, said that the paper by Mr. Bardgett and Mr. Gemmill approached tantalisingly near to a solution of the age-old problem of the effect of aluminium on creep resistance, and he sincerely hoped that the authors would continue this work in an endeavour to reach a final answer.

It had been clearly demonstrated in the paper that aluminium, as such, was not responsible for the variation in creep behaviour. The authors suggested that 0·015 per cent. of soluble aluminium was critical because this amount was necessary to ensure the presence of sufficient aluminium nitride, to cause an appreciable reduction in creep properties. Surely, however, all the results in the paper indicated that nitrogen alone was the critical factor and that the effect of aluminium was simply to remove it from the system as insoluble aluminium nitride.

Although all the steels tested were made by the basic open-hearth process, it was reasonable to suggest that the nitrogen content would vary to some extent. Unfortunately, no mention was made in the paper of the nitrogen content of the various casts. If the total nitrogen were accurately known and the amount present as aluminium nitride subtracted, the final amount might correlate better with the creep properties, and some of the slight anomalies which the authors mentioned might be explained.

(*To be continued*)

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THE FATIGUE OF METALS

Residential Course at Nottingham

A week's residential course on "The Fatigue of Metals" is to be held at the University of Nottingham from Monday, September 12, until Friday, September 16. The course has been organised by a joint committee of industry and the engineering departments of the University under the chairmanship of Mr. G. Forrest, B.Sc., A.M.I.Mech.E., A.F.R.Ae.S., of Aluminium Laboratories Limited.

It is intended that the course should present the known facts concerning the fatigue of metals to the practising engineer, and, although no formal academic qualifications are required for enrolment, it will be assumed that those attending the course will possess either a degree or the Higher National Certificate in engineering or science.

The subjects to be covered comprise: the fundamentals of fatigue, the fatigue properties of steels and cast iron, the fatigue properties of non-ferrous alloys, corrosion fatigue and fretting corrosion, fatigue of aircraft, and fatigue testing.

Applications will be dealt with as received and early enrolment is advised as the number attending the lectures must be limited to approximately 150. The fee for the course, inclusive of advance copies of lectures, is 10 guineas, and the fee for accommodation is 7 guineas.

No applications for entry to the course can be considered after August 27 and all inquiries and correspondence should be addressed to the Secretary, Fatigue of Metals Course, Departments of Civil and Mechanical Engineering, University of Nottingham, University Park, Nottingham.

GAP-GRADED AGGREGATES IN VIBRATED CONCRETE

FUNDAMENTAL STUDIES OF RELATIONSHIPS GOVERNING PARTICLE INTERFERENCE

By T. E. H. Williams, M.SC., PH.D., A.M.I.STRUCT.E.*

A concrete aggregate is said to be gap-graded if one or more of the recognised standard size groups is absent. The gap may occur naturally or may be deliberately produced by screening particles. Many investigators[1, 2] have recognised that any benefit obtained from the use of gap gradings is due to the reduction in the wedging action caused by omission of intermediate sizes. This article is concerned with the analysis of this phenomenon of "particle interference" and the establishment of the principle governing the action of gap-graded aggregates in vibrated concrete.

CONCRETE COMPACTION DURING VIBRATION

To understand the importance of particle-interference effects in vibrated concrete it is necessary to appreciate the mechanism of concrete compaction during vibration. The effect of the vibration is to set the particles in the fresh concrete in motion, reducing friction between those particles and giving the material the mobile qualities of a thick fluid. There are three phases involved in the process of compaction, as illustrated in Fig. 1.

During the first phase of compaction, a rapid subsidence of the loose concrete occurs due to the sudden reduction of inter-particle friction and viscosity; it is during this period that the major-sized particles in the mix settle and form a compact network of solids.

During the second phase of compaction an apparent liquefaction of the concrete and its de-aeration occurs. It is during this phase that the smaller particles attempt to penetrate, with the aid of the mobile cement grout, the voids in the compact major particles. The successful penetration of a void results in the formation of an air bubble which is eventually forced to the surface of the concrete.

The third phase of compaction results in either a general stabilisation of the plastic concrete or in a segregation of the various constituents of the mix. If the mix is not properly proportioned the material present in excess of requirements is forced to the surface of the concrete; this applies equally to the coarse aggregate, fine aggregate, cement and the water.

If the process of compaction is to be a continuous action, the chief requirement for a vibrated concrete mix is a mortar which responds well to the vibration and possesses a high degree of mobility. The mobility of a mortar is mainly controlled by the grading of its fine aggregate and particularly the predominant size of particle. It is thus essential that the mean diameter of the largest size of particle in the fine aggregate shall be less than the mean void diameter of the coarse aggregate if particle interference effects are to be avoided.

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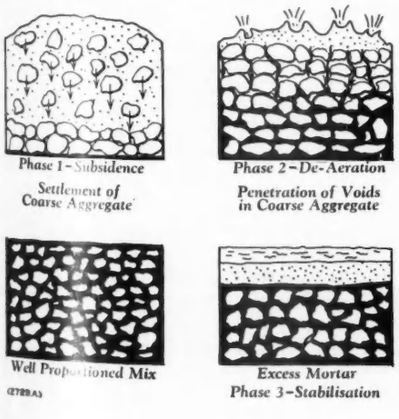

Fig. 1 Phases in the process of concrete compaction by vibration.

Mean Projected Diameter.—In the experiments here described, the mean projected diameter of "single size" particles, that is, the particles retained between two consecutive standard sieves, was determined by measuring the distance between the two extreme points along one particular axis on every particle in a sample. The samples represented a chance distribution of particles with respect to size and shape, so the measurement of diameters in one well-defined direction gave a representative picture of the size distribution in the main bulk quantities.

The particles in the sample were spread arbitrarily on a glass plate of size 3¼ in. by 4¼ in. (Fig. 2, below), together with a standard disc of known diameter. The plate was inserted in a photographic enlarger and the enlarged images of the particles and standard disc were projected upon a sheet of squared paper. The arithmetic mean of all the diameters divided by the magnification gave the value of the mean projected diameter (d_p) of the particles.

In terms of the sieve apertures, the mean projected diameter of "single sized" aggregates was found to be as follows:

$$d_p = 1{\cdot}38 \times (\text{mean sieve aperture}) \quad . \quad (1)$$

where the mean sieve aperture = ½ (sum of the two sieve apertures concerned). This relationship was based on the results obtained for particles of size (¾–⅜ in.), (⅜–$\frac{5}{16}$ in.), ($\frac{5}{16}$ in.—sieve No. 7), (7–14), (14–25), (25–52) and (52–100) and compared favourably with the results obtained by Heywood.[3] The coarse aggregate was an irregular river gravel and the fine aggregate consisted of sharp, irregular shaped sand particles; the value of the constant, 1·38, in equation (1) may not apply to crushed rock aggregate and rounded sand.

Mean Void Diameter.—The mean diameter of void, d_v, of a compacted bed of particles can be expressed in terms of the specific surface S (sq. cm. per gramme) of the particles as follows (Rigden's equation)[4]:

$$d_v = \frac{2{\cdot}53\ \mathrm{E}}{\mathrm{S}\,\sigma\,(1-\mathrm{E})} \quad . \quad (2)$$

where E is the porosity and σ the density (gm. per cubic centimetre).

Substituting the specific surface per unit volume of solid, S_0, for S in equation (2) gives:

$$d_v = \frac{2{\cdot}53\ \mathrm{E}}{\mathrm{S}_0\,(1-\mathrm{E})} \quad . \quad (3)$$

PARTICLE INTERFERENCE: THEORY AND TEST RESULTS

"Single-Size" Aggregates.—Equations (1) and (2) were used to calculate the values of d_p and d_v for single-size coarse aggregate (irregular river gravel) and fine aggregate (sharp irregular sand); the results are given in Table I.

TABLE I.—*Values of d_v and d_p for "single-size" aggregates*

Size of particle (B.S. sieve)	Porosity (E)	Specific surface (S) sq. cm. per gm.	Density (σ) gm. per cub. cm.	(1—E)	Mean void dia. (d_v) (cm.)	Mean projected dia. (d_p) (cm.)
¾–⅜	0·412	2·75	2·57	0·588	0·251	1·97
⅜–$\frac{5}{16}$	0·405	5·00	2·57	0·595	0·134	0·985
$\frac{5}{16}$–7	0·417	11·50	2·73	0·583	0·0576	0·495
7–14	0·415	23·00	2·73	0·585	0·0286	0·249
14–25	0·409	46·00	2·73	0·591	0·0139	0·125
25–52	0·399	92·00	2·73	0·601	0·00668	0·062
52–100	0·385	184·00	2·73	0·615	0·00316	0·031
100–200	—	—	—	—	—	0·016

These calculated values of mean void diameter and mean projected diameter (Table I) suggested certain combinations of particle sizes if particle interference effects were to be avoided. If the ¾-in.—⅜-in. coarse aggregate (of mean void diameter 0·251 cm.) was used these results suggested that the maximum allowable size of fine aggregate particle would be 7–14 (mean projected diameter 0·249 cm.). Similarly, the voids in the ⅜-in.–$\frac{5}{16}$-in. particles should accommodate particles only up to 14–25 size.

The validity of such proposed theoretical relationships was tested by a series of experiments using single-sized aggregates in a dry state. A particular single-size aggregate called the "principal aggregate," was first vibrated to complete compaction in a 4-in. cube mould (of volume V) and another single-size aggregate, called the "secondary aggregate," was poured on its free surface while vibration continued until infiltration of voids was apparently complete. The percentage infiltration (Table II, page 694) was calculated as follows:

$$\text{Percentage infiltration} = \frac{\dfrac{\mathrm{W}_s}{\sigma_s}}{\left(\mathrm{V}-\dfrac{\mathrm{W}_p}{\sigma_p}\right)}\,\frac{100}{(1-\mathrm{E}_s)} \quad . \quad (4)$$

where W_s, σ_s are the weight and density of the secondary (or fine) aggregate; W_p, σ_p, the weight and density of the principal (coarse) aggregate; E_s, the porosity of the secondary aggregate; and V is the total volume.

These test results verificd the derived theoretical relationships; the aggregates listed to the right of the weighted line in Table II had infiltration values greater than 86 per cent. and did not experience particle interference effects. It is of interest to note that as the size of the principal aggregate was reduced from ¾–⅜ to ⅜–$\frac{5}{16}$ (one standard group size) the maximum allowable size of secondary aggregate was also reduced

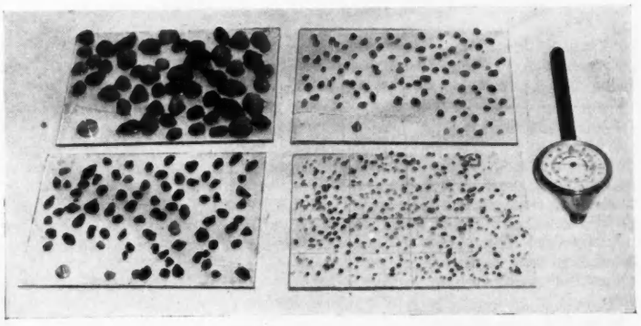

Fig. 2 Determination of the mean projected diameter of the aggregates. Comparisons are made to standard discs of known diameter.

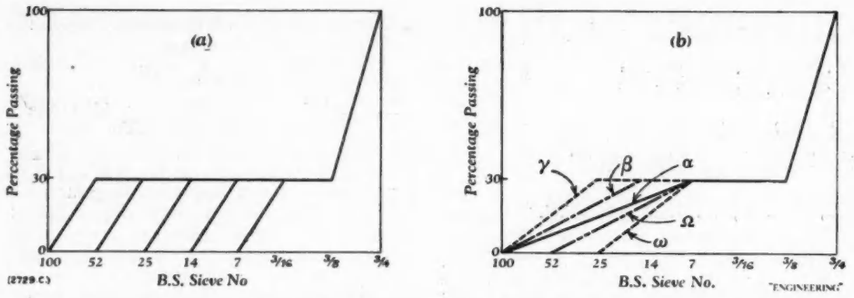

Fig. 3 Gap-graded aggregates, series C1/T, group 1: coarse aggregates, ¼–⅜ in. (a) Single-size fine aggregate, (b) graded fine aggregate.

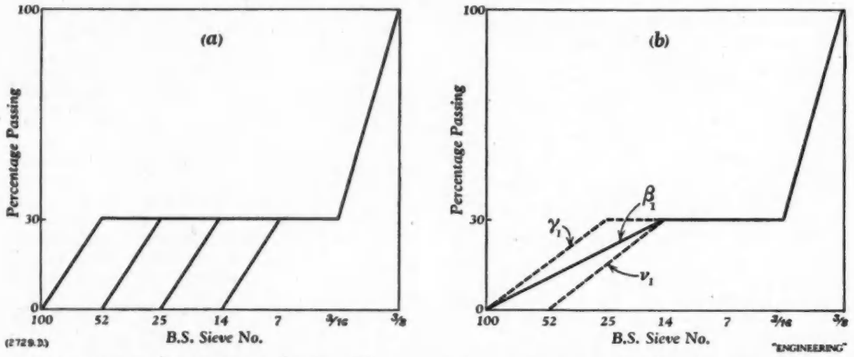

Fig. 4 Gap-graded aggregates, series C1/T, group 2: coarse aggregates, ⅜–⅛ in. (a) Single-size fine aggregate, (b) graded fine aggregate.

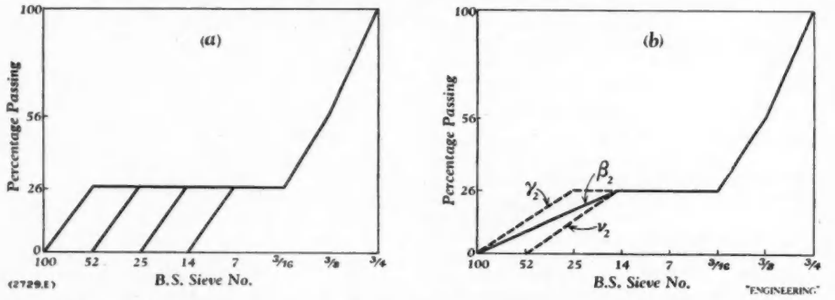

Fig. 5 Gap-graded aggregates, series C1/T, group 3: coarse aggregate, ¼–⅜ in. (a) Single-size fine aggregate, (b) graded fine aggregate.

through one standard group size (7–14 to 14–25). When the principal aggregate size was further reduced one standard group size (⅜–⅛ to ⅛–7) the maximum allowable size of secondary aggregate was reduced through two standard group sizes (14–25 to 52–100). This is explained by the fact that the two principal aggregates in the former case were gravels of approximately similar shape, whereas those in the latter case were different, the ⅜–⅛ being a rounded gravel and the ⅛–7 a sharp irregular sand.

TABLE II.—*Summary of infiltration test results*

Principal Aggregate	Secondary Aggregate—Percentage Infiltration				
	⅛–7	7–14	14–25	25–52	52–100
¼–⅜	18·2	17·5	88·4	93·5	91·5
¼–⅛		11·9	86·7	96·5	94·0
⅛–7				12·2	94·5

Graded Aggregates.—The value of the mean void diameter for a principal aggregate consisting of two sizes of particles, 60 per cent. being of size ¼–⅜, and 40 per cent. of size ⅜–⅛, was calculated as follow :

Porosity of compacted principal aggregate .. 36·1 per cent.
Specific surface of ¼-in. –⅜-in. particles .. 2·75 sq. cm. per gm.
Specific surface of ⅜-in. –⅛-in. particles .. 5·00 sq. cm. per gm.
Specific surface S of combined aggregates = $\left\{\begin{matrix}0{\cdot}6 \times 2{\cdot}75 \\ \text{plus} \\ 0{\cdot}4 \times 5{\cdot}00\end{matrix}\right\}$ .. 3·65 sq. cm. per gm.

Mean void diameter, d_v, is given by

$$d_v = \frac{2{\cdot}53\,E}{S\,\sigma\,(1-E)} = \frac{2{\cdot}53 \times 0{\cdot}361}{3{\cdot}65 \times 2{\cdot}57 \times 0{\cdot}639} = 0{\cdot}152 \text{ cm.}$$

This result suggested that the maximum size of secondary aggregate which could penetrate the voids in this graded principal aggregate was the 14–25 size (d_v = 0·125 cm.). The validity of this result was verified by conducting infiltration tests similar to those already outlined for single-size principal aggregates; the results are listed in Table III.

TABLE III.—*Summary of infiltration test results*

Principal Aggregate	Secondary Aggregate—Percentage Infiltration			
	7–14	14–25	25–52	52–100
¼–⅜	13·5	89·5	93·0	93·0

Gap-Graded Aggregate.—Test series C1/T comprises cubes containing gap-graded aggregates. The three main groups of cubes in this series were made from concretes of ¼-in.–⅜-in., ⅜-in.–⅛-in., and ¼-in.–⅛-in. coarse aggregate, respectively. The main purpose of casting these cubes was to verify that point contact between all coarse aggregate particles was obtained in concrete when the maximum size of particle in the fine aggregate was sufficiently small to penetrate the voids in the compacted coarse aggregate. The aggregate/cement ratio was 1 : 6 and the water/cement ratio 0·50 for every mix in this test series; the complete programme is summarised in Table IV.

The grading charts for the aggregates used in Groups 1, 2 and 3 are shown in Figs. 3, 4 and 5.

The appearance of test cubes 8/7 (Fig. 6, opposite), 16/14 (Fig. 7), and 8/16/14 (Fig. 8), illustrate clearly how particle interference resulted in the segregation of the coarse aggregate. The porosity of the interlocked aggregate was increased and the cement paste flowed to the bottom of the specimen. These three cubes contained fine aggregate of size which would cause particle interference according to the results obtained from infiltration tests (Tables II and III) and therefore verify the conclusions drawn from those tests.

The cubes illustrated in Figs. 9, 10 and 11, opposite, particularly illustrate that the secondary (fine) aggregate can vary widely and will not prevent point contact between the particles of the principal (coarse) aggregate provided the mean projected diameter of the maximum size of single size particle in the secondary aggregate is less than the mean void diameter of the compacted principal aggregate. The maximum bulk densities (Table IV) were obtained when the fine aggregate consisted of more than one group of single-size particles. The occurrence of particle interference resulted in a marked decrease in bulk density, viz., cubes 8/7, 16/14 and 8/16/14.

TABLE IV.—EXPERIMENTAL PROGRAMME. TEST SERIES C1/T

Test Group No.	Cube Ref.	Coarse Aggregate	Fine Aggregate	Bulk Density lb. per cub. ft.	Proportions by Wt. (cement/sand/gravel)
1	8/7	¼–⅜	⅛–7	140·3	1/1·8/4·2
1	8/14	,,	7–14	151·0	,,
1	8/25	,,	14–25	156·2	,,
1	8/52	,,	25–52	155·9	,,
1	8/100	,,	52–100	152·9	,,
1	8/α	,,	7–100	157·7	,,
1	8/β	,,	14–100	157·1	,,
1	8/γ	,,	25–100	155·8	,,
1	8/ω	,,	7–25	152·9	,,
1	8/Ω	,,	7–52	156·7	,,
2	16/14	⅜–⅛	7–14	132·7	1/1·8/4·2
2	16/25	,,	14–25	152·5	,,
2	16/52	,,	25–52	153·3	,,
2	16/100	,,	52–100	150·0	,,
2	16/β_1	,,	14–100	153·6	,,
2	16/γ_1	,,	25–100	152·8	,,
2	16/ν_1	,,	14–52	153·0	,,
3	8/16/14	¼–⅛	7–14	146·5	1/1·56/1·8/2·64
3	8/16/25	,,	14–25	156·2	,,
3	8/16/52	,,	25–52	156·3	,,
3	8/16/100	,,	52–100	154·1	,,
3	8/16/β_2	,,	14–100	156·6	,,
3	8/16/γ_2	,,	25–100	155·3	,,
3	8/16/ν_2	,,	14–52	156·7	,,

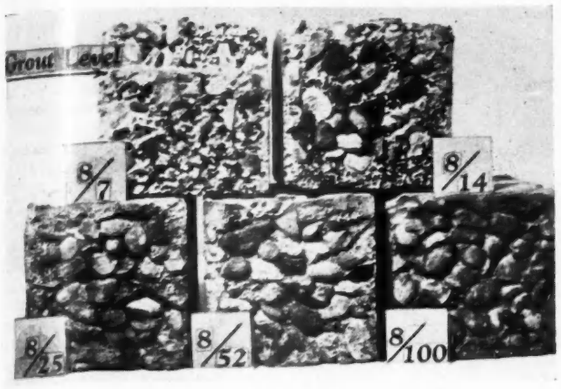

Fig. 6

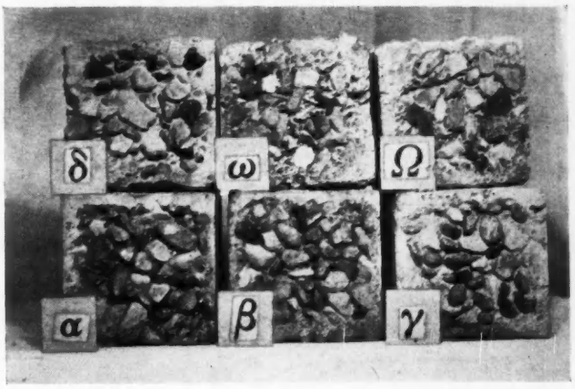

Fig. 7

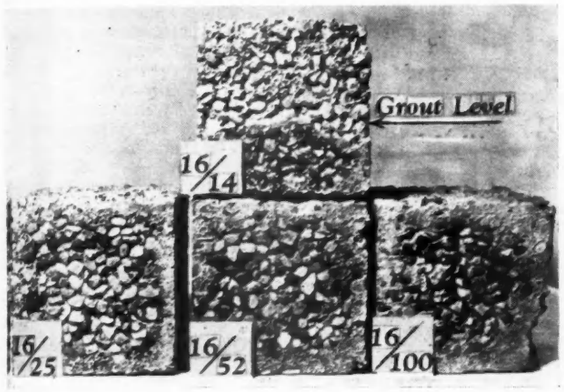

Fig. 8

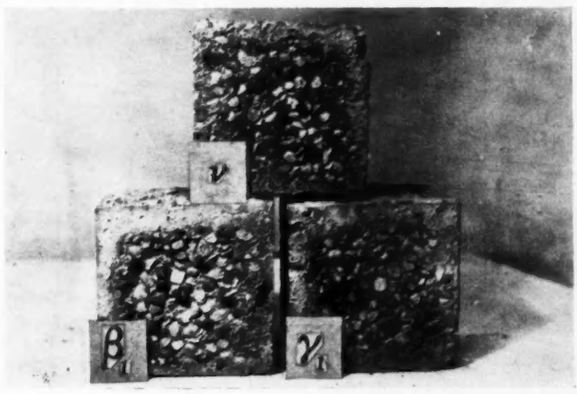

Fig. 9

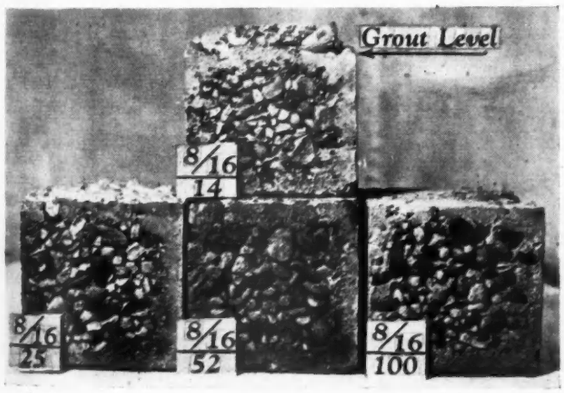

Fig. 10

Figs. 6, 7 and 8 Particle segregation can occur if, as illustrated here, point contact between the coarse aggregate is prevented by particle interference.

Fig. 11

Figs. 9, 10 and 11 Complete compaction is possible with many different fine aggregates provided that their size is limited to the mean void diameter of the coarse aggregate.

VIBRATION TIME AND CRUSHING STRENGTH

The aggregate grading has a critical influence upon the response to vibration of a concrete mix. A high response characteristic means a rapid rate of compaction. The two methods used to determine the differences in response to vibration of various concrete mixes were as follow. *Method* 1: Each mix (at constant water/cement ratio) was subjected to vibration of constant intensity for a fixed time and the crushing strengths compared. Since the crushing strength was dependent upon the degree of compaction, those with the highest strengths showed the highest response to vibration. *Method* 2: Every mix was vibrated to complete compaction and the time taken to reach that state evaluated. Mixes of high response to vibration had the lowest times of compaction.

Fixed-Time Vibration.—Fig. 12, on page 696, shows the graphs obtained for cube-crushing strength against fineness modulus of the total aggregate for mixes of cement/aggregate ratio 1 : 7; the ratio of coarse/fine aggregate was varied (1 : 2 : 5 and 1 : 2·5 : 4·5) and the water/cement ratio was varied (0·40 to 0·52). Three replicate cubes were made from mixes of identical composition and each cube was vibrated at a constant acceleration of $9g$ for the fixed period of 2 minutes. Each plotted result is the mean value of crushing strengths obtained from three nominally identical cubes. The coarse aggregate grading was kept constant (60 per cent. of $\frac{3}{4}$–$\frac{3}{8}$ in. and 40 per cent. of $\frac{3}{8}$–$\frac{3}{16}$ in.) whereas the fine-aggregate grading was varied within the B.S. 882 limits for "Class B" fine aggregates; (these limits are shown in Fig. 13, excluding curves S.1 and S.4, on page 696).

The graphs in Fig. 12, herewith, show that as the fineness modulus increased the strength was constant or increased slightly until a certain optimum value was reached, beyond which the crushing strength decreased rapidly. These optimum values of fineness modulus (F.M.) were 5·475 and 5·220 for the 1 : 2 : 5 and 1 : 2·5 : 4·5 mixes respectively. The aggregates of F.M. values greater than these critical values were the same in both series, and contained fine aggregates S2, 5, 6, 7 and 10, all of which had 35 per cent. (by weight) of their particles retained on a No. 14 B.S. mesh, whereas the remaining

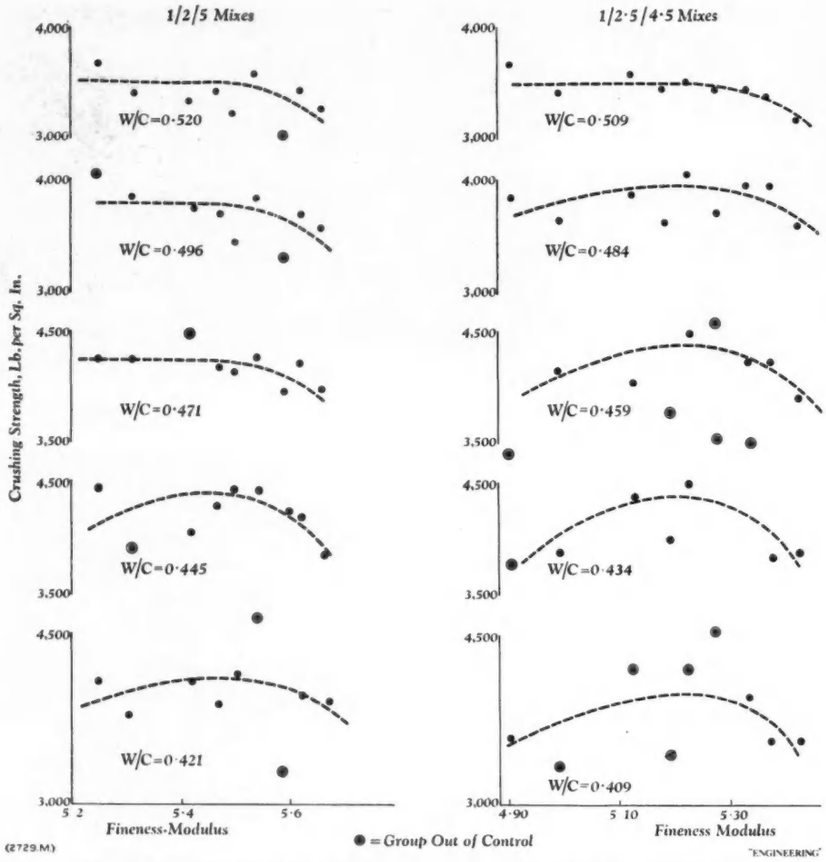

Fig. 12 The variation of concrete crushing strength with fineness modulus of the combined aggregate for different water/cement ratios. The concrete was vibrated for a fixed period of 2 minutes.

four aggregates had only 7·5 per cent. retained on the same mesh.

The infiltration test (Table III) proved that the maximum size of fine aggregate particle which could penetrate the voids in the compacted $\frac{3}{4}$–$\frac{3}{16}$ aggregate was the 14–25 B.S. mesh size. It thus follows that the value of optimum fineness modulus evident in the results of the fixed-vibration-time series was controlled by the predominant size of particle in the fine aggregate. Where the aggregates were of F.M. value greater than the optimum value, particle interference accounted for the lack of compaction and consequent decrease in strength. As the water content of the mixes increased the crushing strengths of the concretes became more uniform. The scatter of results is dependent upon the wetness of the mix and consequent availability of grout or paste. Surplus grout in a mix reduces irregularities in response to vibration by its lubricating action and prevention of locking of particles which would restrict particle movement. When carried to an extreme the introduction of excessive water results in the production of free grout which entirely controls the performance of mixes; it completely obliterates any distinction of grading in concrete.

The trailing-off of strength in mixes of fineness modulus less than the optimum value can be attributed to particle surface-area effects, resulting in incomplete compaction. The lower the F.M. value, that is, the finer the aggregate, the greater the surface area of particles and the greater the viscosity and friction effects.

Complete Compaction.—Fig. 14, opposite, shows the results from a similar series of mixes with the difference that each cube was vibrated to complete compaction. It is seen that the crushing strengths were sensibly uniform; all except two groups, denoted by the encircled dot, were within the normally expected statistical limits ($\pm$ 3 standard deviations).

Similar results were obtained from graphs of crushing strength against mean void diameter of aggregate since fineness modulus is proportional to $\log_{10}$(mean void diameter). Thus, for a fixed period of vibratory compaction the graphs of crushing strength against fineness modulus, or mean void diameter, consist of three definite parts as shown in Fig. 15. The shape of the curve depends upon the water content of the mix and the intensity and duration of vibration. The drier the mix and the weaker or shorter the vibration the more convex (upwards) the curve.

Confirmatory evidence of the existence of optimum F.M. values was provided by the graphs of complete compaction time against F.M. and mean void diameter (Fig. 16). The instant of complete compaction was shown on a recording wattmeter (see Appendix for details).

Hand Compaction and Fixed-time Vibration.—Abrams[5] showed that the strength of a concrete mix of a specific workability was proportional to the fineness modulus of the aggregate. The mixes which he used were all of a specific "plastic condition" and they were compacted by a standard ramming procedure, using a tamping rod of known weight and size; the results he obtained are plotted as curves shown in Fig. 17, herewith. A standard ramming procedure therefore tends to produce an effect on concrete mixes which is similar to that produced by vibratory compaction of fixed duration. The form of general curve concerning vibrated mixes (Fig. 15) has the same trend as Abrams' curves. The peaks on Abrams' curves denoted the value of F.M. which was the most workable for hand-compaction and the peak on the author's curve gives the value of F.M. for maximum response to vibration. When the F.M. value for the aggregate is less than the optimum value for hand compacted mixes it is said to be "too fine"; this corresponds with the "surface area effect" suggested by the author for concrete compacted by vibration. When the F.M. value is greater than the optimum value for hand compacted mixes it is said to be "too harsh"; this condition corresponds with the "particle interference effects" for vibrated concrete mixes. The determination of the maximum size of fine aggregate particle which can penetrate the voids in the compacted coarse aggregate enables the direct location of the optimum F.M. value for the material.

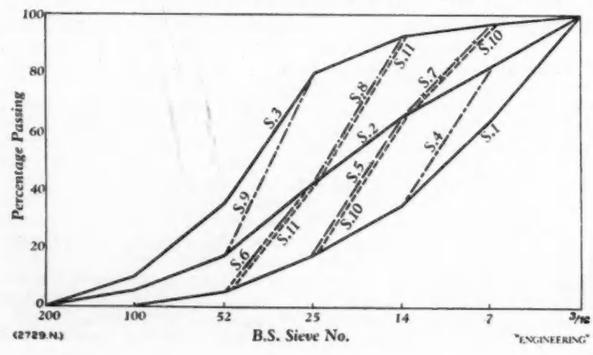

Fig. 13 Grading of the fine aggregate for test series CP, C2 and C2/T.

FINE AGGREGATE GRADING AND CONCRETE STRENGTH

When concrete cubes are compacted by vibration, wide variations in the grading of fine aggregate consisting of particles of the same shape, texture and porosity characteristics have no effect upon the scatter of crushing test results *provided full compaction has been obtained.*[6] This was proved by casting 48 cubes in each of two series. Series C.1 consisted of 1 : 6 concrete of constant water/cement ratio 0·47 (net) with a coarse/fine aggregate ratio of 7 : 3. The gradings of both coarse and fine aggregates were constant for every cube (gap grading: α, Fig. 3). Series C.2 consisted of 1 : 7 concrete of constant water/cement ratio 0·45 (net) with a constant coarse/fine aggregate ratio of 5 : 2. The coarse aggregate grading was kept constant but the fine aggregate grading was varied systematically (S2 to S11 except S4, Fig. 13). Every cube was vibrated to complete compaction and both test series C.1 and C2 were carried out during the same casting period to reduce the effects of non-random errors and to ensure identical treatment of cubes. The values of the coefficient of variation for C.1 and C.2 were 3·73 and 3·82 per cent. respectively. It still remains to be proved whether particles of fine aggregate of widely varying shapes, texture and porosity characteristics produce a significant effect on the consistency of compression test results.

SUMMARY AND CONCLUSIONS

Criterion for particle interference.—The relationship between the value of the mean void diameter for a compacted principle (coarse) aggregate and the mean projected diameter of the particles of a secondary (fine) aggregate was proved to be the criterion for particle interference. When the value of the former was less than the latter, particle interference occurred.

The value of the mean void diameter was

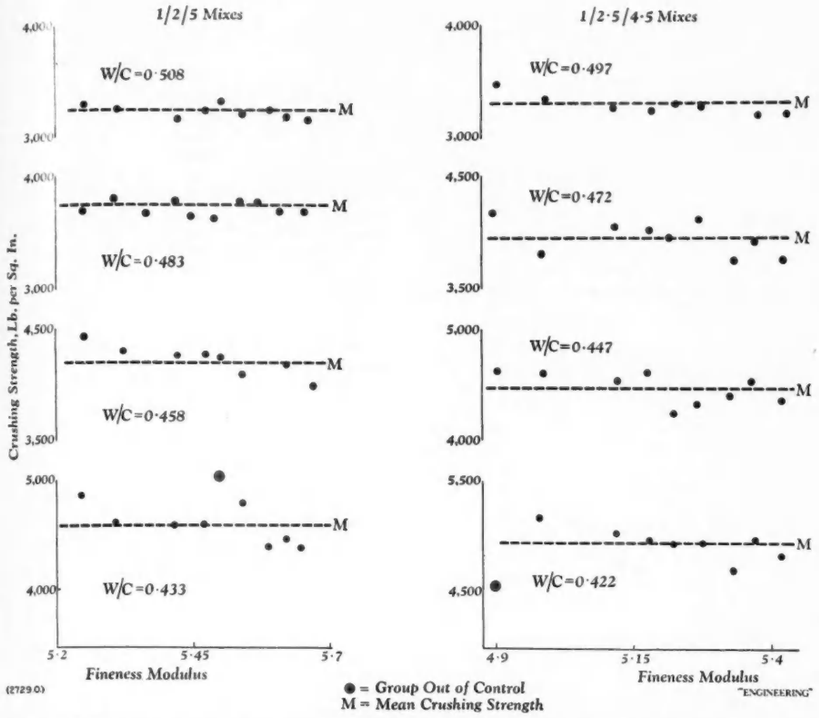

Fig. 14 The variation of concrete crushing strength with fineness modulus of the combined aggregate for the different water/cement ratios. In this series the concrete was vibrated to complete compaction.

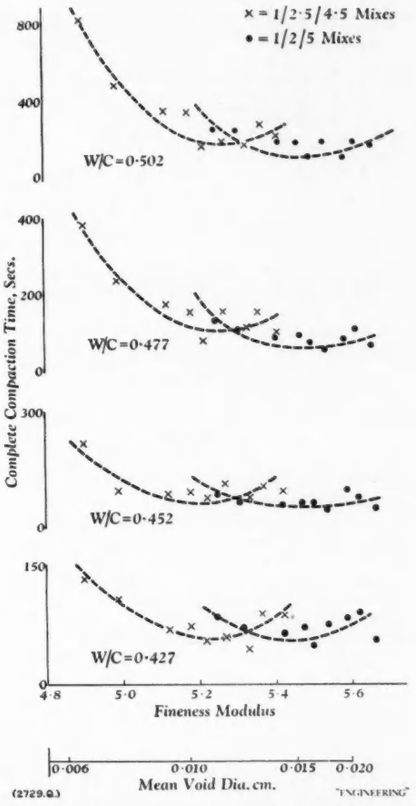

Fig. 16 Time required to attain complete compaction with a varying fineness modulus or mean void diameter of the combined aggregate for four different water/cement ratios.

determined from the expressions:

$$\frac{2{\cdot}53\ E}{S\,\sigma\,(1-E)} \quad \text{or} \quad \frac{2{\cdot}53\ E}{S_0\,(1-E)}.$$

The value of the mean projected diameter of the secondary aggregate particles was determined from the expression:

$$1{\cdot}38 \times \text{(mean sieve aperture)}.$$

This criterion was proved to apply when principal aggregates consisted of one or two groups of "single-size" particles. The grading of the secondary (fine) aggregate was varied widely and did not prevent point-contact between the particles of the principal aggregate provided the mean projected diameter of the maximum size of "single-size" particle in the secondary aggregate was less than the mean void diameter of the compacted principal aggregate. Concrete aggregates must therefore be gap graded if particle interference effects are to be avoided. Maximum bulk density (lb. per cub. ft.) was generally found to be obtained when the secondary aggregates contained the maximum possible number of groups of "single-size" particles.

Aggregate Grading and Fixed-time Vibration.—The aggregate grading has a critical indirect effect upon the crushing strength of concrete compacted by vibration of fixed duration and intensity. For aggregate in a particular concrete mix an optimum value of fineness modulus exists which is controlled by the mean void diameter of the principal (coarse) aggregate. Aggregates of F.M. greater than the optimum are susceptible to particle-interference effects. Aggregates of F.M. less than the optimum value are susceptible to excessive surface area effects (friction and viscosity).

Aggregate Grading and Vibration to Complete Compaction.—The grading of the secondary (fine) aggregate does not affect the scatter of crushing test results obtained from concrete

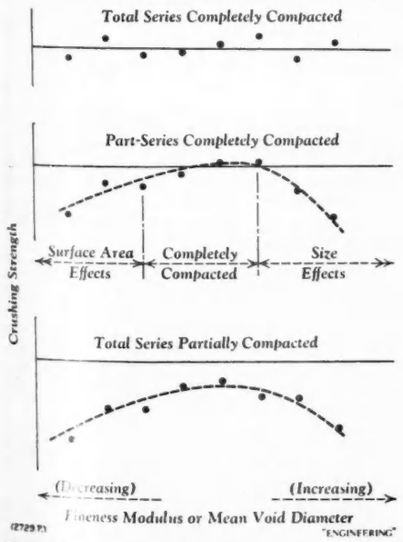

Fig. 15 The relationship between crushing strength of the concrete, fineness modulus or the mean void diameter of the aggregate, and the degree of compaction attained.

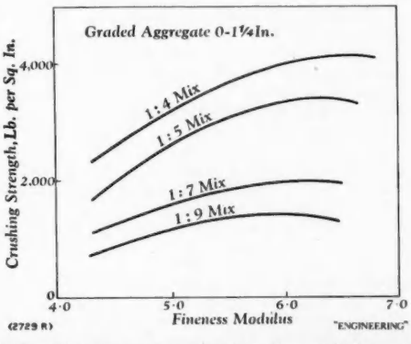

Fig. 17 Abrams' curves for the variation of crushing strength with fineness modulus for different mixes.

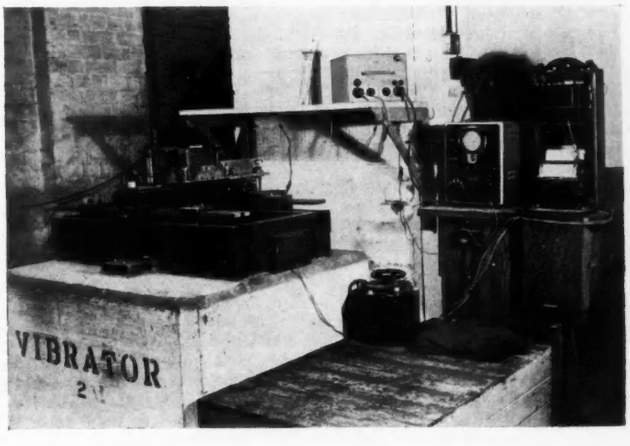

Fig. 18 Vibrating table and ancillary apparatus; the table oscillated at twice the frequency of the voltage supply.

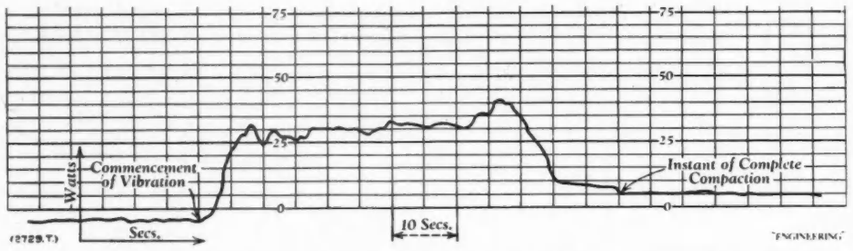

Fig. 19 Typical wattmeter record showing the input of electrical energy during compaction; complete compaction is indicated by re-occurrence of uniformity in the input as the concrete vibrates in resonance with the machine.

compacted by vibration, provided complete compaction has been obtained. It has, however, a critical effect upon the time required by the mix to reach the state of complete compaction.

APPENDIX

Vibrating Table and Measuring Apparatus

The layout of the vibrating equipment used in all the experiments referred to in the text is shown in Fig. 18 on the previous page. It shows the Westool-Stewart research type vibrating table, which consists of a platform supported on springs whose lengths are adjustable. An armature attached to the underside of the platform is actuated by an electro-magnet bolted to the base of the table, the electro-magnet being energised from alternating-current mains supply.

The table vibrates at twice the frequency of the voltage supply, that is, 6,000 cycles per minute on a 50-cycles per second supply. The number of effective turns of wire on the electro-magnet is adjustable. The amplitude of vibration is controlled by feeding the power to the electro-magnet through a Variac transformer. The system vibrates vertically with simple harmonic motion, and can be set to resonate at any platform load by adjusting the position of the spring supports.

The amplitude measuring system consisted of a pick-up in the form of a differential transformer, connected to a cathode ray oscillograph. The width of trace on the cathode ray tube screen could be controlled within $\pm 0{\cdot}5$ mm.; this represented an accuracy of 1 per cent. on the setting used during the tests, when the displacement magnification obtained was 100.

An oscillator, used to energise the pick-up coils, and a recording wattmeter to measure input, completed the ancillary equipment. The wattmeter showed when the state of full compaction had been achieved in the concrete, since when all the enclosed air had been expelled the concrete vibrated in resonance with the rest of the vibrating unit and the input of electrical energy was a minimum. Fig. 19 shows a typical wattmeter record.

Acknowledgments.—The author acknowledges the helpful guidance of Professor W. Fisher Cassie and the assistance received from the Research Committee of King's College, Newcastle-upon-Tyne (University of Durham); from Dr. H. Heywood concerning specific surface determinations; and Mr. D. A. Stewart and Mr. A. L. Hunking of Westool Limited, West Auckland, who supplied the vibrating table.

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RADIO RESEARCH IN 1954

REVIEW OF PROGRESS

As the greater part of the work carried on or sponsored by the Radio Research Board of the Department of Scientific and Industrial Research is of a long-term character, it will be readily understood that the annual report of the chairman, Sir Noel Ashbridge, can only explain the nature of the work and review the progress made during the year. The report for 1954, recently issued,* however, includes the report of the Director of Radio Research, Dr. R. L. Smith-Rose, who deals with the work in greater detail.

WAVE PROPAGATION

Although the research activities of the department are confined to radio, this covers a wide field, including long-distance and local communications, sound and television broadcasting, point-to-point communication links, and radio navigational aids, including radar. For these branches of radio a very wide range of frequencies is employed so that the highest frequency in use is a million times the lowest. The whole frequency range, however, is already overcrowded and each new service introduced renders the problem of interference still more acute. For this reason it is becoming increasingly important that the operating conditions and location of transmitters working on adjacent frequencies should be based on accurate knowledge of wave propagation. This subject is therefore regarded as of primary importance in the research programme of the Board.

A fund of knowledge and experience in this field is being built up and is available to civilian and defence authorities using radio services, as well as to manufacturers of equipment. One of the directions in which the Radio Research organisation makes an important contribution to British efforts in this field is in forecasting ionospheric conditions, the forecasts being used by all British authorities concerned with long-distance broadcasting and point-to-point communications; they are applied in choosing the best frequencies for current use and in planning new services. In radio direction-finding also the work of the organisation has demonstrated the importance of errors attributable to propagation and has indicated certain steps which can be taken to reduce them. The use of higher frequencies for television and sound broadcasting has necessitated measurements in these bands, but further investigations are required, particularly in Bands IV and V (470-585 and 610-960 Mc/s), which are higher frequencies than are intended for immediate use in this country, and at even higher frequencies there are important propagation problems connected with the operation of radio relay links. It is pointed out in the report that, with the resources available at present, it has not been possible to deal adequately with these problems, but it is stated that the work will be proceeded with as soon as opportunity offers. An interesting point concerning the rather lower frequencies used in the short-wave band for long-distance communication and broadcasting arises from the fact that at these frequencies the energy from the transmitter reaches the receiver after one or more reflections between the ionosphere and the earth's surface. At the present time, the properties of the ionospheric layer mainly concerned are fairly steady, neglecting the daily and seasonal variations, owing to the fact that the 11-year cycle of sunspot activity is now at its minimum. Thus a convenient opportunity is provided to review the scope of ionospheric research, and this is being done by Dr. Smith-Rose in consultation with the two committees mainly concerned.

INVESTIGATIONS OF MATERIALS

Another field in which fundamental research is being carried out concerns the properties of certain special materials used in radio components and equipment. At the Radio Research Station the element germanium is being studied because of its increasing use in transistors. The electrical properties of the material and of components made from it are being examined so that the inherent physical processes involved may be more clearly understood. One of the main lines of research has been the examination of the fluctuating currents (noise) present in point-contact and junction diodes when these are biased in the non-conducting direction. These noise currents have been observed over a frequency range extending from 0·01 cycle per second to 2 Mc/sec. Measurements of such noise spectra have also been made on filaments of monocrystalline germanium, care being taken to ensure that the electrodes are substantially non-rectifying. Measurements made of the impedance and current amplification factor of an alloy-type junction transistor have provided confirmation of some features of the theory of transistor action.

Studies of the crystallographic, electrical and magnetic properties of ferrites have been carried out at Imperial College, on behalf of the department. At the same college a centimetre-wave spectrometer for examining the properties of artificial dielectrics is now ready for use. Prisms of suitable composition will be constructed with the object of finding structures showing a rapid change of refractive index with wavelength. One of the first to be tested will consist of an array of thin wires mounted in polystyrene. Such structures could be applied, for example, in a radar scanning aerial, so that by a small change in the frequency of the transmitter the direction of the beam could be quickly varied.

In addition to the work on materials at Imperial College, the efforts applied to the programme of research have been augmented by contracts placed by the department with the Universities of Cambridge and Wales, where investigations into ionospheric wave propagation are in progress. Research on the propagation of surface waves in the centimetre waveband is also in hand at University College, London.

INCREASED ACCOMMODATION

Hitherto, the work of the Laboratory has been hampered by the fact that it has been necessary to use temporary buildings in the grounds of the Admiralty Compass Observatory at Ditton Park. The report states, however, that the construction of new permanent buildings for the laboratory at Slough was commenced in May, 1954, and that they are expected to be ready for occupation by the end of the current year. The new buildings will be capable of accommodating a much larger staff than is at present engaged, but there is no doubt that there will be sufficient problems to occupy them. It is feared, however, that the recruitment of the additional staff, particularly of the scientific officer class, may take some time owing to the shortage of highly qualified engineers and physicists which exists throughout the country.

* *Radio Research* 1954. H. M. Stationery Office, 2*s*. 6*d*.

HIGH-ALTITUDE LABORATORY

DEVELOPING AIRCRAFT-CABIN PRESSURE SYSTEMS

The high-altitude laboratory of Normalair, Limited, Yeovil, in which are carried out research and development testing of the control elements for aircraft cabin-pressure systems, is believed to be one of the most extensively equipped in Europe. In this laboratory it is possible to test complete systems at any desired pressure altitude at temperatures from below −60 deg. C. up to those of the tropics, and under pressure differences up to 1 atmosphere.

Towards the end of the second World War, a large decompression chamber, Reavell exhauster and Hall refrigerator were installed. The decompression chamber (Fig. 1) is still the largest rig in use, but has in the course of time been modified. Originally it was designed to house representative fuselage sections of pressurised aircraft. For experimental work on components, however, it is desirable to operate at pressure differences considerably higher than the aircraft cabin will be expected to withstand, and the representative fuselage structures available were inadequate for such purposes. In 1950, therefore, a permanent steel pressure cabin was installed within the decompression chamber, capable of sustaining a differential pressure of 1 atmosphere.

Today, in addition to the large decompression chamber in which complete systems are tested under simulated flight conditions, the laboratory houses a climatic chamber in which components can be tested under extreme temperature conditions; a vacuum chamber (No. 1 rig) in which pressure controllers and discharge valves are tested; a vertical chamber (No. 2 rig) which can be used either as a vacuum or as a pressure chamber, more usually as the latter for " blowing-off " safety valves; and a recently-constructed high-altitude rig (No. 3) for carrying out tests similar to those done in the main decompression chamber but without temperature simulation. Most of these chambers are constructed from old steam boilers. In addition to these permanent rigs, tappings from the network of pressure and vacuum pipelines serve for carrying out tests on components.

The laboratory has its own fitting section in which all the rigs, etc., are constructed, and a standards room in which strip inspections are carried out as well as calibration of the measuring instruments used. There is also, within the main laboratory, a small oxygen research laboratory which has its own decompression chamber (No. 4 rig) for carrying out personnel tests on oxygen breathing apparatus, which is manufactured by Normalair, for use by air crews.

Adjacent to the laboratory is the production testhouse which also houses an altitude chamber for simulated flight tests of components, a number of bench altitude test rigs with small cylindrical vessels representing the cabin in which pressure controllers, etc., can be mounted, and a pressure rig for checking safety valves. The production test rigs are served by the same pressure and vacuum plant as the high-altitude laboratory.

ENGINEERING PLANT

The engineering plant is contained in a power house separated from the high-altitude laboratory by a sound-proof wall. The main pressure and vacuum lines are led to the laboratory through ducts under the floor and also at roof level and, as already mentioned, can be tapped at various points in the laboratory. The vacuum plant comprises four Hick, Hargreaves exhauster sets, in addition to the original 60-h.p. electrically-driven Reavell vacuum pump which has a capacity of 10 lb. per minute at a pressure corresponding to an altitude of 40,000 ft.

The Hick, Hargreaves sets originally comprised four vane-type rotary vacuum pumps, size RV.17, coupled in pairs and driven by V-belts from Diesel engines which, at the time of installation, were the type of prime mover most readily available. Each pair of vacuum pumps was to reduce the pressure in the chamber to that corresponding to an altitude of 61,000 ft., and at this pressure to be capable of handling a mass flow of 12 lb. a minute. The pressure was to be variable at any figure between atmospheric and the minimum specified. This installation was subsequently modified by the addition of a similar, but smaller, machine to act as a second stage to each of the existing pairs. This second stage was driven independently by its own electric motor, the piping being so arranged that it need only be brought into service when required to provide increased performance needed to reduce the pressure to that corresponding to an altitude of 70,000 ft. and to be capable of handling at this pressure a mass flow of 10 lb./hr. The maximum equivalent altitude that can actually be attained, is considerably higher than the specified figure. This installation is illustrated in Fig. 2, below.

Subsequently a further installation of four RV.17 machines, each driven by an independent motor and each having an independent motor-driven second-stage machine to provide the higher altitude conditions, has been installed. The use of multiple machines provides for the maximum flexibility and economy in operation to meet the very fluctuating demands of a test and research plant. The vacuum pumps are of standard Hick, Hargreaves construction, with water-cooled cylinders and end covers, and fitted with restraining rings to take the outward thrust due to centrifugal action of the steel blades.

Two Northey rotary two-stage exhausters serve tapping points in the oxygen laboratory and also the decompression chamber used for testing oxygen apparatus. The manner in which the various exhauster sets can be connected with the main pipelines feeding the test rigs can be seen in Fig. 3.

Three Reavell reciprocating compressors, each with a capacity of 120 lb. per minute at 18 lb. per square inch pressure and driven by a 35-h.p. electric motor, provide the pressure supply to the de-compression chamber, the vertical pressure chambers and the altitude test chamber (No. 3 rig). The latter is also served by a recently-acquired Hollands three-stage rotary compressor with a capacity of 150 lb. per minute at 150 lb. per square inch. This compressor, which also charges pressure vessels in the production-test-house, is driven by a Ruston Paxman eight-cylinder four-stroke marine Diesel engine incorporating a Napier turbo-blower and rated at 750 brake horse-power (12-hour) at 750 r.p.m.

The Worthington Simpson compressor shown in the pipeline layout (Fig. 3) is used for supplying constant-flow valves at 12 lb. per minute up to pressures of 175 lb. per square inch. High surge flows, up to 50 lb. per minute for short periods, can be obtained on this rig.

REFRIGERATION

Fig. 4 shows the Hall two-cylinder refrigerator compressor, driven by a 125-h.p. electric motor, which has a capacity of 56,000 B.Th.U. per hour at 0 deg. C. and can reduce the air temperature down to — 50 deg. F. The refrigerator, which uses methyl chloride as refrigerant, is used in conjunction with a brine storage tank which feeds the " cabin " cooler in the decompression chamber; it also serves directly evaporator coils in the decompression chamber and in the air-conditioning circuit. The latter, which also incorporates a circulating fan, a 22-kW heater, and an air dryer, is used to supply conditioned air to the climatic chamber and to the decompression-chamber cabin.

VACUUM AND HIGH-ALTITUDE RIGS

Returning to the rigs in the high-altitude laboratory, the vacuum chamber (No. 1 rig) which is illustrated in Fig. 5, is divided into two sections, either of which can be held at any altitude with a high degree of precision. The larger of these two sections is 13 ft. 6 in. long, 6 ft. in diameter, and has a volume of 390 cub. ft. The smaller chamber has a capacity of 20 cub. ft. The control valves regulating the rate of change

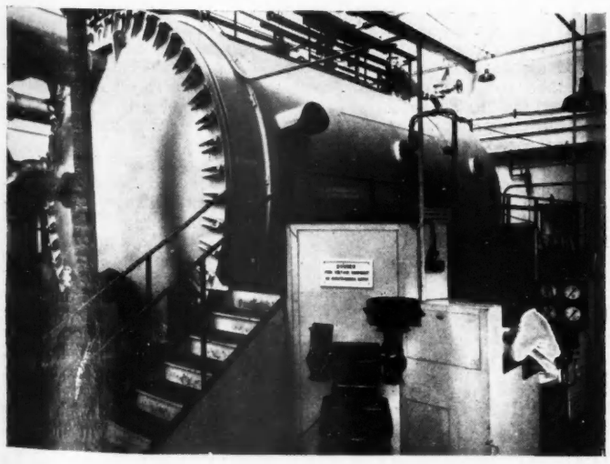


Fig. 1 The main decompression chamber, within which is a permanent steel pressure cabin capable of withstanding a differential pressure of 1 atmosphere.

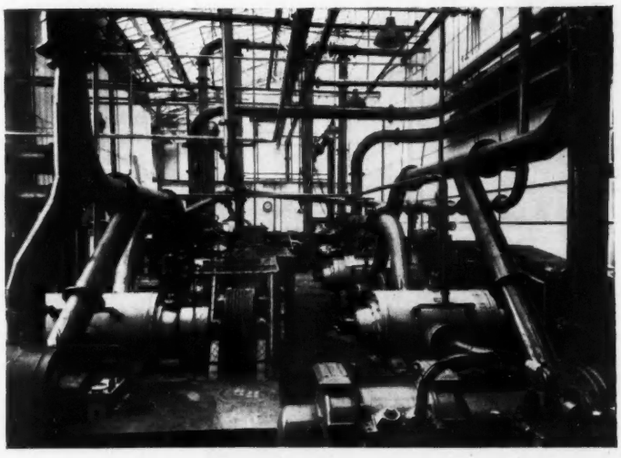


Fig. 2 Two of the four sets of Hick, Hargreaves rotary exhausters which can raise the " altitude " of the decompression chamber to 100,000 ft.

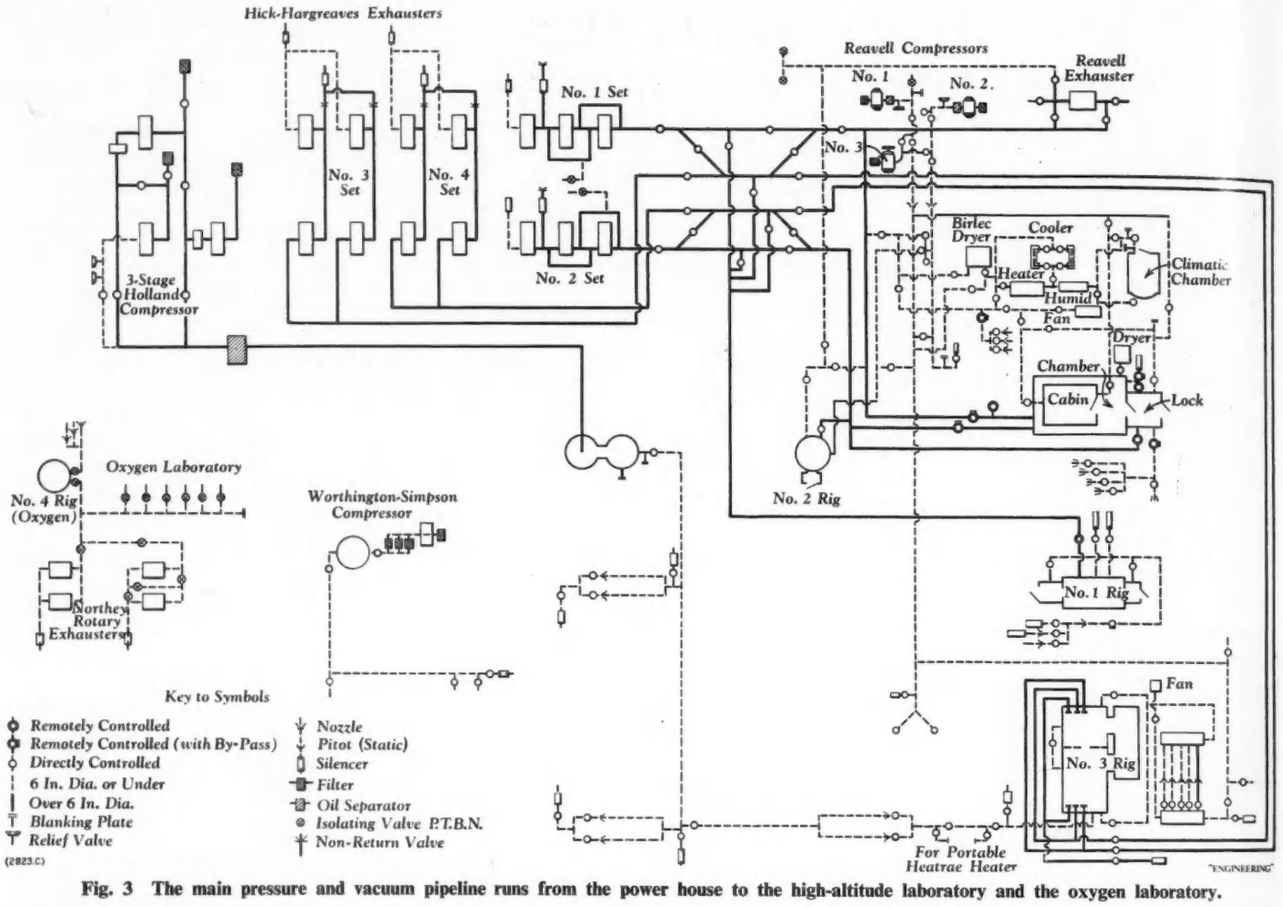


Fig. 3 The main pressure and vacuum pipeline runs from the power house to the high-altitude laboratory and the oxygen laboratory.

of altitude are remotely controlled by the test observer by reference to aircraft-type altimeters and rate of climb indicators.

In Fig. 6 is shown the high altitude test chamber (No. 3 rig) in which altitudes up to 100,000 ft. can be simulated. In the lower pressure vessel are two chambers, one at each end of the vessel. One of these constitutes the working chamber which is used to simulate the pressurised aircraft cabin and is lagged with sound-proofing material; it is separated from the altitude chamber proper —which is not sound-proofed—by a bulkhead on which can be mounted discharge valves under test. Above the lower pressure vessel is mounted a capacity chamber which can be connected to either the working chamber, if it is desired to simulate a cabin of large capacity, or to the altitude chamber for a larger ambient volume. The altitude chamber is used for testing components such as would normally be stowed in the aircraft wing. The respective capacities are: working chamber, 568 cub. ft.; altitude chamber, 1,136 cub. ft.; and capacity chamber, 565 cub. ft.

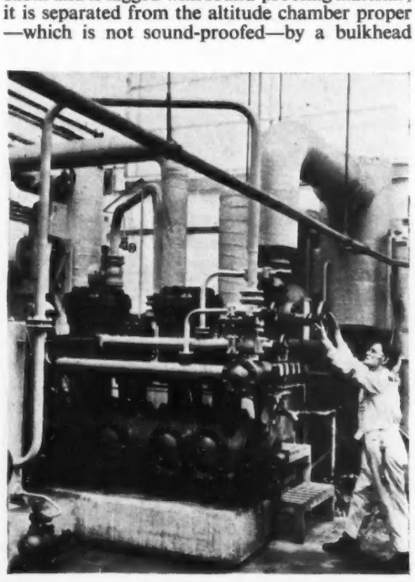


Fig. 4 The Hall two-cylinder refrigerator has a capacity of 56,000 B.Th.U. per hour at 0 deg. C.

In this rig the control valves are manually operated. Either of the lower chambers can be connected to the main vacuum lines, or to an atmospheric bleed to allow air at atmospheric pressure to enter the evacuated chamber. It is also possible to connect the two chambers to equalise pressure. Compressed air for raising the pressure in the working chamber to simulate the aircraft cabin is supplied from the Hollands compressor and/or the Reavell compressors, a range of metered ducts being incorporated in the rig to allow for selecting the desired mass flow. The supply of pressure air can be regulated automatically in accordance with a pre-determined "rate of climb," or manually by reference to a water manometer. By suitably regulating the exhaust and bleed valves, any desired "manoeuvres" or any type of failure can be simulated.

In addition to the aircraft-type cabin altimeter and aircraft altimeters and rate-of-climb gauges, mercury and water manometers are incorporated in the control desk for pressure measurement.

AIR-CONDITIONED DECOMPRESSION CHAMBER

The main decompression rig (Fig. 1) comprises three chambers: the vacuum chamber, the pressure cabin housed within the vacuum chamber, and the air lock through which the vacuum chamber is entered. The cabin can be supplied with up to 120 lb. per minute of conditioned air—dried or humidified, heated or cooled—up to a pressure of 15 lb. per square inch gauge, and can operate between temperature limits of −50 deg. F. to +160 deg. F.

The vacuum chamber, 29 ft. long and 14 ft. in diameter, has an effective volume of approximately 1,500 cub. ft. It is built up from $\frac{5}{8}$-in. rolled mild steel sheet in three sections, welded together on the circumferential seams. The domed end plates are of $\frac{3}{4}$-in. mild steel, one being welded to the cylindrical body and the other bolted with 48 $1\frac{1}{2}$-in. diameter set screws. Strengthening webs are welded across the flange on each side of the set screws. The joint is sealed effectively by a rubber joint ring of $1\frac{1}{2}$-in. square section. The vacuum chamber is lagged with 12 in. of Kapok faced with cedar board, providing effective thermal insulation. Armoured glass windows, comprising two 2-in. plates with an airspace, provide for observing the interior, and are arranged to line up with similar windows in the pressure cabin.

The air lock, which is not lagged, is made from $\frac{3}{8}$-in. mild steel and is cylindrical in section, with a length of 6 ft. and a diameter of 7 ft. 6 in. It is secured to the domed end of the vacuum chamber by 64 $\frac{3}{4}$-in. by $2\frac{1}{2}$-in. bolts through flanges welded to the end of the chamber and the body of the air lock. The end plate of the air lock, of $\frac{1}{2}$-in. mild steel, is welded internally and externally to the body. Access between the chambers is through hinged air-tight doors sealed by soft rubber cushions, additional insulated doors being provided for use during the climatic tests.

The vacuum chamber is provided with methyl chloride cooling coils, supplied from the main refrigeration compressor, and two electrically-driven circulating fans, which direct the flow of cooled air by way of adjustable guide plates to "scrub" the walls of the cabin.

The pressure cabin, which has a volume of

about 1,100 cub. ft., is 14 ft. long and 10 ft. in diameter, is of ½-in. mild steel with domed ends welded to the cylindrical body, and is supported on cradles in the vacuum chamber (Fig. 7). It is designed to withstand an internal pressure of one atmosphere with an external pressure of 2 lb. per square inch. It is designed to represent the interior of a commercial transport aircraft, with Fibreglass heat insulation supported by a wooden framework and arranged, above floor level, in two layers to form an air space or wall duct between. A departure from aircraft practice is the use of expanded metal sheeting to maintain the shape of the wall duct. The interior is finished with a soft leather trim cloth. For measuring the heat loss, 50 platinum resistance-wire thermometers are attached to the inner cabin wall under the insulation. The leads from these are taken to a terminal pad on the wall of the decompression chamber.

Below the cabin floor (Fig. 8) is an air-conditioning system similar to that of an aircraft. Air supplied through a 6-in. bore pipe enters the cabin through a spill valve, by way of a mass-flow metering head and controller, to a brine-cooled heat exchanger, of 26,000 B.Th.U. capacity, and thence through a humidifier to a mixing box. Here it is mixed with recirculating air, drawn from extraction ducts by a fan, and fed to a controllable (1 to 10 kW) electric heater. From here, the treated air passes through a bifurcated duct to the wall ducts on each side. Butterfly valves control the output to the wall ducts.

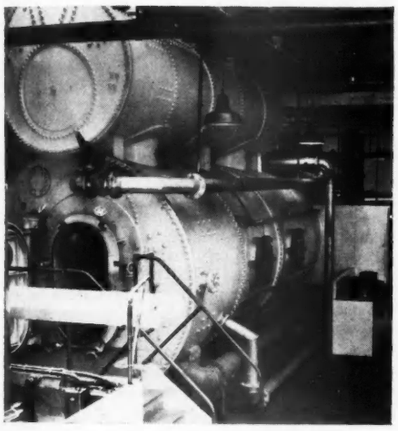


Fig. 6 The high-altitude test chamber. The lower vessel is in two sections—the vacuum chamber and the working chamber which can simulate the pressure cabin. The upper pressure vessel, providing additional capacity, can be connected to either of the lower chambers.

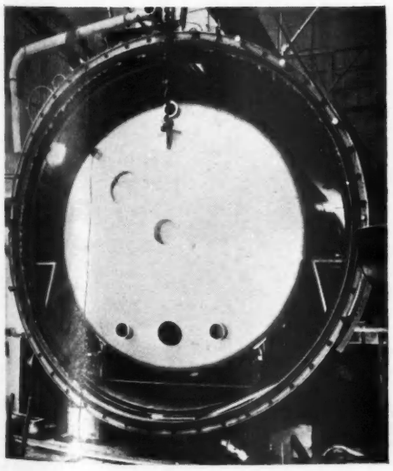
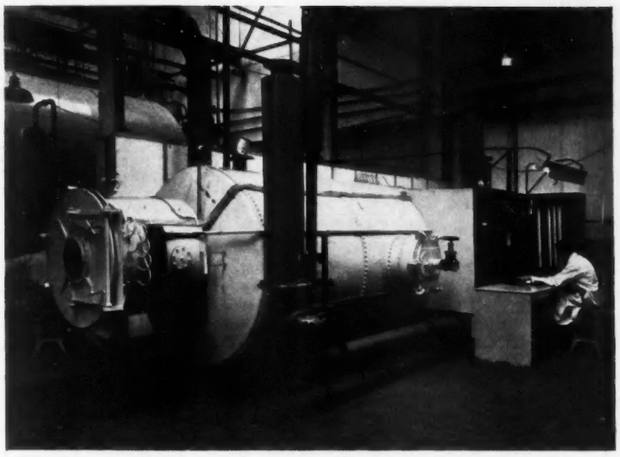


Fig. 7 The steel pressure cabin, 1,100 cub. ft. in capacity, installed in the decompression chamber which has an effective volume of about 1,500 cub. ft.

Fig. 5 The vacuum chamber is divided into two chambers, either of which can be held at any desired altitude so that different tests can be carried out simultaneously.



Within the cabin is a control panel on which are mounted the pressure controllers and the necessary rate-of-climb, altitude, and temperature measuring instruments. The discharge valve (through which stale air is exhausted), safety valve and inwards-relief valves serving the system are mounted below the cabin door. For carrying out tests on new types of valves, a number of experimental mounting flanges are provided on the walls and bulkheads and below the cabin floor.

In addition to the control desk within the pressure cabin, there is a main control desk outside the decompression chamber, and either can be used to control the cabin system through electrically-operated remote controls; the valves controlling the main pressure and vacuum lines to the rig are hydraulically operated from the main outside desk. Intercommunication and loudspeaker systems, together with a flashing-light emergency signalling system, allow the cabin observer and the outside test observer to keep in touch with each other. It is possible for test personnel, suitably clad, to walk about inside the vacuum chamber during a test, since oxygen supplies are provided to points within the air lock, the vacuum chamber and the pressure cabin.

TEMPERATURE CONTROL: FUTURE FACILITIES

As experience with pressurised aircraft has been gained, it has become apparent that a cabin air-conditioning system—embracing heating, humidifying and refrigerating units and controls as well as air-flow and pressure controls—is most satisfactorily engineered as a whole by a single design and development organisation. For this reason Normalair Limited have recently extended their agreement with the AiResearch Corporation, Los Angeles, U.S.A.—a two-way agreement which began during the second World War—to cover the manufacture under licence of all components required for cabin air-conditioning control, including AiResearch cold-air units (of the turbine type) and their pneumatic temperature control system which employs no electrical elements.

To cater for these new developments, the laboratory premises are to undergo a substantial expansion. Already a turbine test rig has been installed in the production test laboratory, in which the calibration curves of pressure drop and temperature drop across the turbine with speed are determined. The rig comprises a control desk behind which is a sound-proof pressure vessel in which the cold-air unit and its associated ducting are mounted. Cooling coils supplied from the main refrigerator plant are used to lower the air temperature to 35 deg. F. and thus reduce the moisture content of the air.

A new test house is now under construction, and is expected to be in operation in a few weeks, to accommodate five turbine test cells, three of which will be commissioned as soon as they are completed; the other two will be reserved for future developments. This plant will cater for any aircraft cold-air unit at present available. To serve the new test cells, three four-cylinder Broomwade compressors, delivering 40 lb. per minute at 150 lb. per square inch, will be installed and will be arranged so that their outputs can serve a common supply line. There will be a 50-kW Heatrae heater and a small Hallmark dew-point refrigerator for each cell. The rigs will be automatically-controlled by Anhim temperature and pressure controls and Moore regulators. In addition to the turbine test cells, the new test house will accommodate balancing machines for turbine rotors.

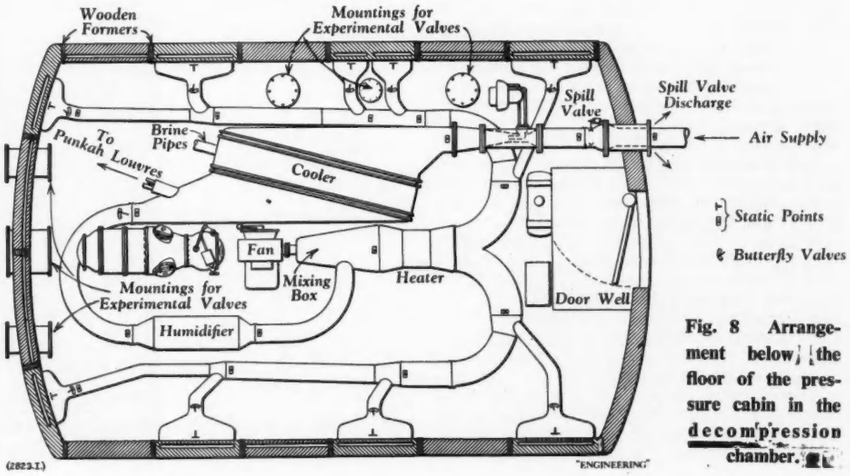


Fig. 8 Arrangement below the floor of the pressure cabin in the decompression chamber.

RUST-PROOFING LARGE BRIDGE GIRDERS

Metal Spraying Before Erection

To replace the existing Black Bridge at Hook, near Basingstoke, which carries the A30 trunk road over the four-track main railway line, the Butterley Company, Limited, Ripley, Derbyshire, have fabricated four steel plate-girders which are claimed to be the largest of their type yet made in this country. Each girder is 128 ft. long, 10 ft. deep, and 2 ft. wide across the top and bottom flanges. They have been fabricated completely in the Butterley Company's works for rail transport to the site. The erection is being undertaken by Caffin and Company, Limited, London, W.C.2.

For protection against corrosion the girders have been sprayed with aluminium by the Schori process. A coating 0·003 in. thick has been applied over the whole surface of each girder, except on the undersides of the bottom flanges, where it is 0·006 in. thick to give added protection against fumes from railway locomotives.

The girders were first prepared by grit-blasting, and then sprayed by means of a Schori metal-spraying pistol, both the grit-blasting and the spraying being carried out at the works of the fabricators by Schori Metallising Process, Limited, Brent-crescent, North Circular-road London, N.W.10, who used mobile equipment of their own design. The grit-blasting was done at a rate of approximately 80 sq. ft. per hour, the power being supplied by portable air compressors of conventional pattern. The blasting medium was crushed flint, which breaks to sharp, angular grains, and gives an excellent bright, clean surface ready for spraying.

After grit-blasting, the cleaned surface was covered with aluminium sprayed on by the Schori pistol, which takes its metal feed in the form of a powder from a small container, and passes it through an annular flame of propane and oxygen. The metal particles are then propelled by compressed air on to the surface being sprayed, where a mechanical bond of great strength results. Aluminium spraying of the Black Bridge girders was carried out at a rate of 120 sq. ft. per hour for the 0·003 in. coating, and 60 sq. ft. per hour for the 0·006 in. coating.

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ELECTRICAL INSTALLATION CONTRACTING

Board Designate Appointed

On February 25 (page 249) we reported that a National Inspection Council for Electrical Installation Contracting was to be set up to prepare a roll for the United Kingdom, the Channel Islands and the Isle of Man and Eire of electrical contractors who had given evidence of their competency. It is now announced that the national inspection board designate held its first meeting on Monday, May 2, when Mr. P. V. Hunter was elected chairman. This body will now proceed with the inauguration of the new Council, and will then function as the National Inspection Board, which will be an executive body charged with the day-to-day business of the Council.

The National Inspection Board will consist of 16 members representing the Central Electricity Authority, the Area Boards, the South of Scotland Electricity Board, the Institution of Electrical Engineers, the Electrical Contractors' Association, the Electrical Contractors' Association of Scotland, the Association of Supervising Electrical Engineers, the Association of Consulting Engineers, the Electrical Trades Union and the Electrical Power Engineers' Association. A nomination has also been invited from the Royal Institute of British Architects.

The duties of the Council will be to protect consumers against faulty or unsafe electrical appliances by assessing the qualifications of contractors who apply to be placed on the roll.

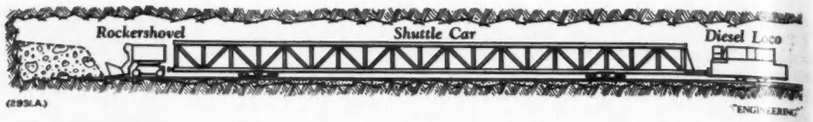


Fig. 1 The general mucking-out arrangements at the working face. The shuttle car, 70-ft. long, had a steel-slat conveyor floor that continuously moved the spoil away from the face and enabled all the fallen rock after shot firing to be loaded on to the car. The car was then withdrawn from the tunnel for unloading, again making use of the conveyor floor.

AN EXPERIMENT IN HIGH-SPEED TUNNELLING

An experiment recently undertaken by the civil engineering contractors, Marples, Ridgeway and Partners Limited, 2 Lygon-place, London, S.W.1, was concluded this spring in Argyll, at the Allt-na-Lairige tunnel, which they have driven by novel methods for the North of Scotland Hydro-electric Board. The following is based on an article by Mr. H. J. Alexander, the contractors engineer at the site.

The Allt-na-Lairige tunnel forms part of a scheme which, although not one of the major hydro-electric works now under way in Scotland, has some unusual features, including a pre-stressed dam—the first of its kind in Western Europe. The tunnel will convey water 6,600 ft. through a hill to the penstock where it drops some 700 ft. to the turbines and thence into Glen Fyne.

Methods employed in driving this tunnel were novel and included unusually high air pressures for drilling the rock, and the use of a special shuttle car designed and built by the contractors to take the complete round. This car has a hydraulically propelled slat floor which moves the rock slowly back as required to make room for more spoil.

FACE DRILLING

The tunnel is only 8 ft. high by 6 ft. 6 in. wide and had to be driven through granite. This small section, and the nature of the rock, made a pull of much more than 7 to 8 ft. per cycle unlikely but it was decided, despite these somewhat unfavourable conditions, to attempt a high-speed face advance. Results did in fact show a substantial improvement on previously recorded figures for this type of work. Attention was directed to the drilling and mucking parts of the cycle, which take a high proportion of the total cycle time. Air pressure was substantially increased, supply pressure being raised from a normal 80 lb. per square inch or so to 115 lb. per square inch at the face. The rock drill is already a highly-stressed piece of equipment but it was decided that the risk of premature breakages was worth taking. Holman " Silver 3 " Handrils, Airleg-mounted, were chosen for this work and three machines were employed to drill the average 21-hole pattern, with a further three standbys used in rotation. At the completion of the tunnel each " Silver 3 " had drilled approximately 30,000 ft. and replacement was no more than usual with any rock drill at normal air pressure.

Tungsten-carbide tipped Holsteels of $\frac{7}{8}$-in. hexagon section with $1\frac{1}{2}$-in. diameter bits were employed. To avoid loss of time on changing, 8-ft. steels only were used throughout. The severe combination of hard rock and heavy blow with vibration of the long unsupported rod resulted in high fatigue stresses, tending to shorten the life of the steels, but a check near the end of the work indicated that the average life was then about 300 ft. drilled, which, in the circumstances, was considered to be good. It was found that the 8-ft. holes could be consistently drilled in just over 4 minutes, and the overall drilling speeds (including time for moving from hole to hole) were 18 to 20 in. per minute throughout the period of work. Total drilling time was thus cut to under 35 minutes per cycle.

Broken rock was loaded out using an Eimco " RockerShovel." The tunnel size was about the minimum for this machine and the loading rate was high, particularly with the increased air pressure, but overall speeds were dictated largely by the facilities for removing spoil from behind it. The width of tunnel here prevented any chance of fast car-changing. It was felt that any of the usual methods of car-changing would result in more loss of time than was generally expected, and that the special shuttle car would ensure continuous loading out.

SHUTTLE CAR DESIGN

An outline drawing of the car, which is now registered under provisional patents, is shown in Fig. 1, and the shovel and locomotive in Figs. 2 and 3. The main frame is 70 ft. long and is carried on two eight-wheel bogies. The chassis is supported on stub-axles integral with the bogie frame and the floor of the body consists of a steel-slat conveyor-belt on rollers, propelled by hydraulic rams. The loaded rock is thus

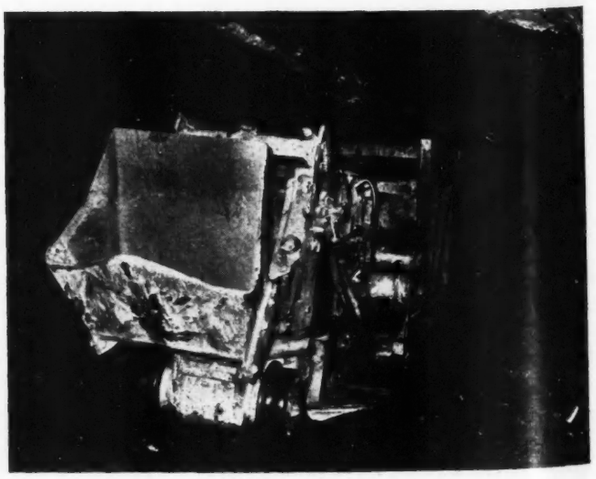


Fig. 2 The Eimco " RockerShovel " used for throwing the spoil on to the shuttle car. The limited space is clearly evident.

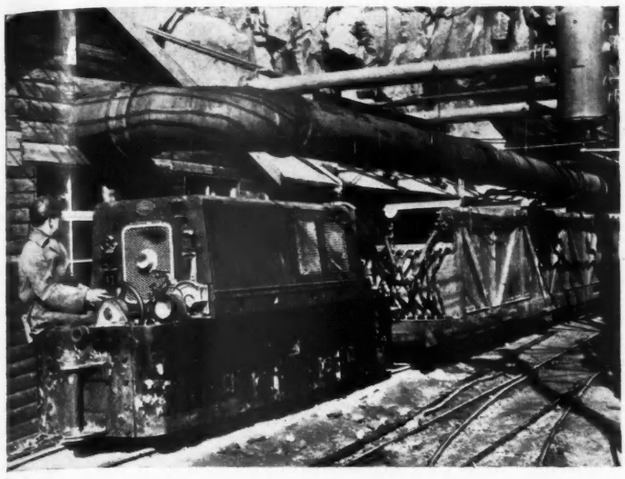


Fig. 3 The Hibberd locomotive used for moving the mucking-out train. Remote control of the locomotive was also possible from the loading end of the shuttle car.

moved steadily back as required to make room for the the new spoil. Some doubt was felt as to the amount of friction which might occur between the stationary side plates and the moving rock. As well as possible difficulty in coping with stress and wear, trouble was expected because it was thought that rock at the sides would move more slowly than that in contact with the belt. Only a moderate pull, however, was required on the belt of the shuttle-car and rock movement was entirely satisfactory. The load was discharged through a space at the bottom of the car at the rear into tubs of 2 cub. yd. capacity, after being withdrawn from the tunnel.

Satisfactory working of the car was not achieved without various delays and modifications. All work on the site was carried out at the tunnel portal on a crowded and exposed shelf located on the steep hillside. On one occasion during a gale the car, weighing about 12 tons, was blown bodily sideways off some timber baulks on which it had been placed. Conditions were thus far from ideal for experimental work of this kind and during the period of teething troubles several thousand feet of tunnel were driven by normal loading-out methods, using small cars and passing bays. In spite of the difficulties of this system good performances were recorded. Mucking times before and after the introduction of the special car make an interesting comparison. The previous best time of about 80 minutes was reduced to 42 minutes for the same depth of pull.

The behaviour of such a large car on the track inside the tunnel was a possible source of trouble. No special care was taken in laying the 2-ft. gauge track of 30-lb. rails, but running on the carefully-designed bogies proved to be very smooth at speeds up to about 8 m.p.h., both laden and empty. Curves of a minimum radius of about 120 ft. could be negotiated. Towing was by a modified version of the 38-h.p. 4.DS-U Diesel underground locomotive built by F. C. Hibberd and Company, Limited, who also collaborated in designing remote controls which could be operated from the loading end of the car, 70 ft. away. Hydraulic power for the conveyor belt was taken from an engine-driven pump in the locomotive.

TUNNEL VENTILATION

Still more time was saved by the high capacity of the ventilation system. The supply was stepped-up to the exceptional figure, for this face area, of 7,500 cub. ft. per minute operating at a pressure of 60 in. water gauge. Two Holmes lobe-type blowers of 35 and 85 h.p. were used. Both were run to clear gas after blasting and during the mucking period; re-entry to the smoke-free face was possible within 10 minutes of shot firing. Diesel-oil fumes were also rapidly cleared by this system. The ventilation and compressed-air pipes were chain-slung from the roof by eye bolts screwed into ½-in. diameter "Rawlplugs" and the holes for these were drilled with a small Holman "Silver 8 Handril" mounted directly on the piston-rod end of one of their Airlegs to form a light stoper drill.

Other features of the work followed normal practice. Although shorter working hours might have improved times still further, the usual 12-hour shift system was employed. Face labour requirements were small, the crews being made up as follow: one shift boss, three drillers, two spanner men, one loader operator, one locomotive driver, and one handyman, making a total of nine.

By the time the shuttle-car was in regular service, cycle times were so short that an attempt was made at an optimum figure for a working week. During the seven-day period commencing March 31, 67 cycles were completed, despite loss of more than a shift on recitfying minor faults on the car. In the seven days the tunnel was driven 444 ft. Had the tunnel not then been almost finished, further improvement could have been reasonably expected.

The general results confirmed the contractors' belief that there is plenty of room for improvement on normal tunnelling methods, and justified the somewhat expensive experimental work on the large shuttle-car. The tunnel is now complete but plans are in hand for further development and marketing of the car and it is thought that much larger sizes could be made on the same principle.

The consulting engineers to the North of Scotland Hydro-Electric Board for the Allt-na-Lairige project are Babtie, Shaw and Morton, Blythswood-square, Glasgow, C.2. The principal manufacturers of equipment mentioned above are the contractors, Marples, Ridgeway and Partners, who designed and built the shuttle-car; Holman Brothers, Limited, Camborne; Eimco (Great Britain), Limited, Wortley-road, Leeds; and F. C. Hibberd and Company, Limited, Park Royal, London, N.W.10.

* * *

HIGH-TEMPERATURE STEAM GENERATION

An American Investigation on Corrosion and Metallurgical Stability

For more than 25 years the Engineering Foundation, 29 West Thirty-Ninth-street, New York, has been sponsoring research in fields of interest to the leading engineering societies, especially those of its founders, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. In addition, it has been contributing a considerable portion of the income from its endowments to the advancement of the engineering profession with special attention to education.

While the results of this support have been published as papers in the proceedings of the leading professional societies, it is felt that they are not widely known to engineers at large. It has therefore been decided to prepare short descriptive articles on some current projects of general interest and one of these on the subject of high-temperature steam generation appears below.

This statement points out that research has already made it possible to improve the efficiency of electrical generation by the use of higher steam temperatures and pressures. To achieve further efficiency in this direction has, however, become more difficult, owing to the severe corrosive action of high-temperature steam and the lack of metallurgical stability in the materials available for superheater tubing.

THE CORROSION PROBLEM

The corrosion problem has been under attack for a number of years. Between 1936 and 1942 a special research committee of the American Society of Mechanical Engineers sponsored work on it at Purdue University. This research was re-established in 1949 as a project to study the possibility of using a regenerative steam cycle at temperatures up to 1,650 deg. F.

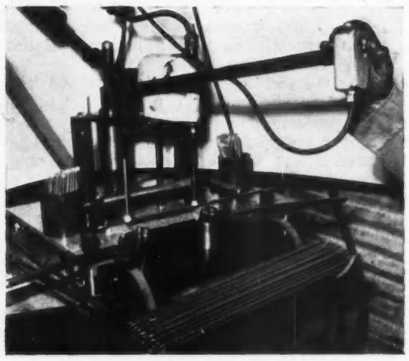
Four factors are being studied at the present time: the properties of the oxide films formed on steel exposed to high-pressure steam at temperatures between 1,100 and 1,500 deg. F.; the resistance of superheater steels to the gases encountered with commercial fuels; the metallurgical stability of the materials during high-temperature service for periods up to three years; and the effect of repeated thermal shock.

Laboratory tests with synthetic atmospheres have been completed, as have field tests on eleven different generating units. According to these tests, several available steels are capable of satisfactory service when delivering steam at temperatures up to 1,200 deg. F. except when certain types of residual oils and waste fuels are burned.

New tests, that promise to be widely significant, will be made at the Philip Sporn Station of the American Gas and Electric Company, where steam is available at a pressure of 2,000 lb. per square inch and a temperature of 1,000 deg. F. For these tests, special apparatus has been designed in co-operation with the United States Navy Bureau of Ships. Electric superheaters and counterflow heat exchangers will be installed in the plant to provide the required steam temperatures. This steam will be passed through five test racks of identical design. Racks one and two will contain specimens of selected ferritic steels maintained at 1,100 and 1,200 deg. F., respectively. In the other three racks there will be specimens of selected austenitic steels, which will be maintained at 1,200 deg., 1,350 deg. and 1,500 deg. F. It will be some five or six years before this test programme is completed, as exposure of the specimens to high-temperature steam for a minimum of three years is necessary.

EFFECT OF HEAT TRANSFER

The effect on heat transfer of the corrosion products formed by steam on the inside of steel tubes is now being studied in special equipment which has also been designed and installed at Purdue University. In this project, steam is passed in series through a counter-flow heat exchanger and electric superheater, which delivers steam at 1,000 deg. F. The steam is then led through two identical heat exchangers in series, one of which contains a clean tube and the other a corroded tube of the same steel. By measuring the flow and the temperature rise through the two heat exchangers in series, the effect of scale on heat transfer can be determined. The thickness of the scale and its metallurgical characteristics will also be investigated.



The welding jig illustrated here, stud welds two ¼-in. diameter pins on to a rod ⅜ in. in diameter. After welding, the two pins are bent to the finished shape by the two hand levers, the complete operation requiring only 25 seconds.

STUD WELDING ON SMALL CURVED SURFACES

Mass Production Bench Jig

To facilitate economical mass production of flare pickets, the Crompton Parkinson Stud-Welding Organisation, a section of Crompton Parkinson, Limited, Crompton House, Aldwych, London, W.C.2, has recently developed a technique to enable ¼-in. diameter pins to be stud welded to the curved surfaces of ⅜-in. diameter rods. This application proves that stud welding can be carried out with success on curved surfaces of small radius, and it will undoubtedly give rise to many further applications for stud welding in this field. The application, moreover, is also of interest as an example of jig construction for speeding up a repetitive manual task. By the method employed, an operator can accurately locate and weld two ¼-in. diameter mild-steel pins—5·8 in. and 6·3 in. long, respectively—to the 1 ft. 11 in. long, ⅜-in. diameter mild-steel picket rod, and then bend each pin at right-angles at a pre-set position along its length, all in a "floor-to-floor" production time of only 25 seconds. The flare pickets have been ordered by the Mason Engineering Company, Limited, Northampton.

The complete operation is carried out in the following manner. The picket rod, to which the pins are to be stud welded, is placed on V-blocks so that it abuts against an end stop. One of the pins, together with a special concave ferrule, is then loaded into the welding head, which is mounted on a swivel above the V-blocks so that it can be lowered to either of the two welding positions. The location of the welding head is fixed by means of pillar slides which limit the swivelling movement; other pillars act as end stops to limit the downward movements. When loaded, the welding head is lowered down the left-hand slide by use of a counterweighted lever, the first weld being effected by pressure on the push-button switch which is mounted conveniently on the lever. For the second weld, the operations are repeated with the welding head travelling down the right-hand slide. This is shown in the illustration above.

The bending of the pins is then accomplished by rotating the picket rod through 90 deg. and clamping it in the V-blocks so that the pins lie flat in a double-handed bending fixture, the handles of which can be seen swung outwards in the illustration. Operation of the bending device then effects the two right-angle bends simultaneously and the completed picket is removed by releasing the clamps.

The method of producing the flare pickets is straightforward, the work being reduced to a brief series of simple operations which enable mass-produced articles of consistent quality to be manufactured without any particular skill being required on the part of the operator. Thus the combined use of bench-mounted stud-welding heads and simple jigs, designed on lines similar to the installation described, clearly has possibilities in other directions.

* * *

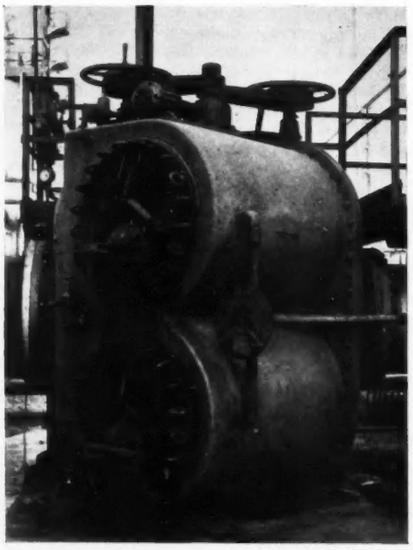
STRAINERS FOR SEA WATER

Requirements for Removing Large Amounts of Solids

Where large quantites of sea water are used for cooling purposes, as at the Fawley refinery of the Esso Petroleum Company, Limited, it is necessary to include special strainers for the removal of solids. In addition, there may be considerable contamination from trade effluents, which is liable to cause corrosion.

In the initial layout at Fawley, coarse screens were fitted at the intakes, but these blocked quickly, were difficult to clean and also allowed a large amount of the smaller debris to pass into the heat exchangers. To overcome this difficulty, twin strainers of the type illustrated below and made by Royles, Limited, Irlam, Manchester, were incorporated in the systems. The largest were those for the catalytic cracking plant which had to handle 23,500 U.S. gallons per minute. Each of these strainers was 30 in. in diameter. The static operating pressure was 45 lb. per square inch gauge and the maximum allowable pressure drop across the strainers was 5 ft.

However, it was found that though these were straining the water satisfactorily, they were not able to cope with the enormous quantities of matter involved. Cleaning had to be carried out every few hours and the standard cleaning doors proved too small, necessitating the complete removal of the cage. This was a comparatively lengthy process, requiring four men. Therefore, special strainers were constructed with a strengthened cage to withstand frequent removal, and a quick-release door clamped by a capstan screw as shown. The piping by which the pressure on the two sides of the changeover valve is balanced, before switching from one strainer to the other, was enlarged and the switching mechanism motorised. In addition, all interior iron surfaces were coated with Neoprene by the Synchro process to prevent the corrosion which had been observed in some places.



To handle the enormous amount of debris in sea water used for cooling systems, the strainers have been fitted with quick-release doors, strengthened cages and Neoprene linings.

When a potential of 12 kilovolts is applied to the filter cells the efficiency of collection of 1-micron dust particles increases from 45 per cent. to 70 per cent.

REMOVING DUST FROM AIR

Combined Mechanical and Electrostatic Filter

An air filter incorporating mechanical and electrical cleaning is being manufacted under licence from the American Air Filter Company, Incorporated, by Air Control Installations, Limited, Ruislip, Middlesex. It is called the "Electro-Klean," and each unit, one of which is shown in the illustration above, comprises a mild steel frame containing one or more filter cells. These cells are supported in the frame between two metal grids, one charged and the other earthed, which produce a strong electrostatic field in the filter media to attract and hold the dust and smoke particles.

Each filter consists of a mineral-fibre filter medium. The medium is composed of fine filaments compressed into a thin porous sheet, bonded together at each point of contact with a thermoplastic under heat and pressure, and finally accordion-pleated. The edges of the pleated medium are coated with a metallic compound that contacts the grids and serves as a conductor to ensure uniform distribution of the electrostatic charge over the entire filter cell.

The power pack, shown on the left-hand side of the unit in the illustration, is supplied at 210 to 250 volts alternating current, 50 cycles, and gives an output of 500 micro-amps at between 11·5 and 12·5 kilovolts. There are two indicator lamps on the front of the power pack, the red one showing that the mains supply is connected, and the white one showing that the electrical system is operating correctly.

If the filter is used to purify air which is not initially too dirty, it is claimed that the filter cells will only need changing at intervals of five months. In places where the cleaning duty is heavier the cells can be rapped to remove dust and then replaced. When extracting filters for replacement or rapping, safety devices ensure that the supply is off and that the filters are earthed to dissipate any electrostatic charge.

The filter unit can be used uncharged, when the collecting efficiency is 85 per cent. of particles down to 3 microns and 45 per cent. of particles down to 1 micron. If the electrostatic charge is applied the efficiencies are 95 per cent. of particles down to 3 microns and 70 per cent. of particles down to 1 micron.

ORPHEUS TURBOJET TYPE TESTED

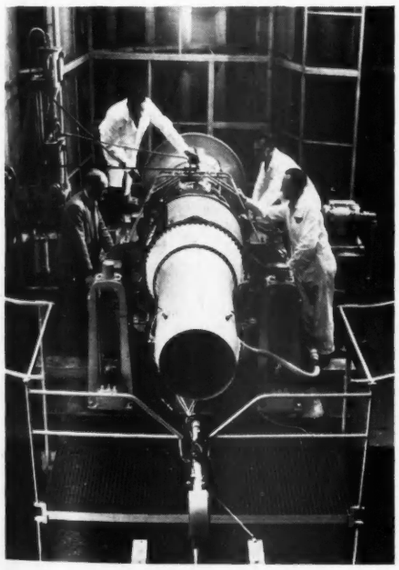
Thrust/Weight Ratio 4·4

The Orpheus lightweight jet engine constructed by the Bristol Aeroplane Company, Limited, Filton, Bristol, will be exhibited in public for the first time at the Paris Salon, the international display which opens at le Bourget on June 10.

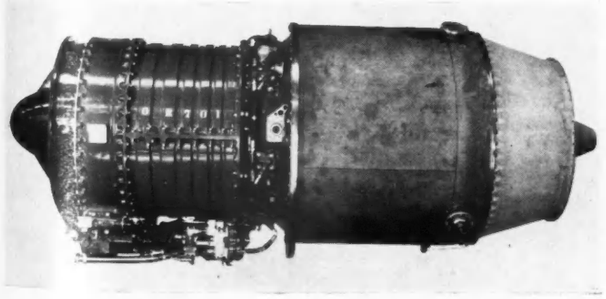
The Orpheus, which is the specified power unit for the Folland Gnat, the Fiat G.91, the Breguet Taon, the Dassault Mystere 26 and other light fighter aircraft, has recently completed a 150-hour type test, during which it achieved a thrust of 3,285 lb. The corresponding thrust-to-weight ratio of 4·4 lb. thrust per lb. weight is the highest yet attained by a type-tested engine. Other versions of the Orpheus under development are already running at higher thrusts.

Development of the Orpheus was initiated in late 1953 as a private venture, but is now the subject of a Ministry of Supply contract, and is likely to be ordered in quantity for lightweight interceptors and ground-attached aircraft for the NATO forces. Its development has been exceptionally rapid. The engine first ran on December 17, 1954, and since then over 1,500 hours of test-bed running have been completed. Five engines are now available for bench tests.

The main considerations in the design of the Orpheus have been low weight, low cost, and easy maintenance. Accessories and internal gearing have been kept to a minimum to keep the weight down; low cost follows directly from the concentration on weight saving and simplicity, without recourse to unconventional methods for cutting costs. For easy maintenance, all the accessories are grouped on the underside of the engine. Items requiring attention have been kept to a minimum, and the engine can be completely stripped in a few hours.

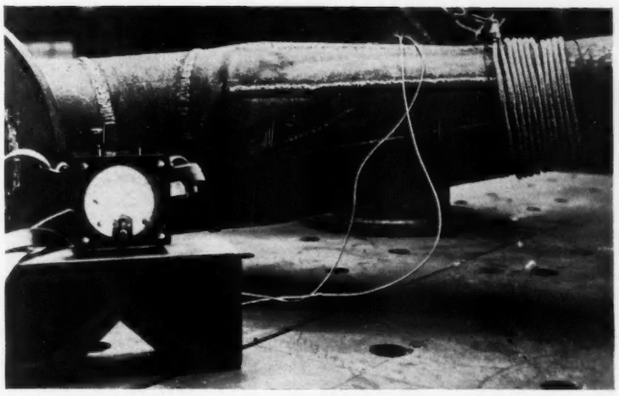


Orpheus turbojet on the test bed.



The Bristol Orpheus turbojet, specified for the Folland Gnat and several other light-weight fighter aircraft, has successfully completed a 150-hour type test. It is designed for low weight, low cost and ease of maintenance.

By wrapping armoured heating cables around the joints, the parent metal can be pre-heated or welds can be stress-relieved at temperatures up to about 750 deg. C.



ARMOURED HEATING CABLES

Pre-heating and Stress-relieving in Situ

A range of armoured heating cables has been produced by Electrothermal Engineering, Limited 270 Neville-road, London, E.7, for the purposes of pre-heating before welding, and for stress-relieving after welding, such items as cannot easily be moved from site or which would be difficult to place in a furnace. Oil pipelines, high-pressure steam pipes, and processing vessels are typical examples.

The operation is as follows. First, the thermocouple junction should be attached to the area being treated—possibly by insertion in a slot which is afterwards peened over. Then a piece of welding-rod is tacked on to the working face to form a grip for the collar of the heater cable. The latter is next wound (without overlapping) tightly round the section in question, as is illustrated on the right, The other end of the heating cable may be fixed in the same way. To the two heater ends are attached the leads from the power supply; these require some thermal insulation. Better thermal efficiency is also obtained by lagging the whole of the heated area and about 18 in. on each side of it. Maximum thickness of lagging may be as much as 3½ in.

To quote an example, a 9-in. diameter alloy-steel pipe having a wall thickness of ⅜ in. was heated from 12 deg. C. to 700 deg. C. in 45 min.; a 2-in. layer of asbestos tape was used as lagging. The watts/voltage characteristic of the heaters is not quite a straight-line relationship, but at 80 volts the heating power is approximately 2,000 watts increasing to 5,000 watts at about 128 volts. Three different cable lengths of heater are made: 16 ft., 20 ft. and 24 ft. Thermocouples, compensating leads and pyrometers can also be supplied to work with these heaters.

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LAUNCHES AND TRIAL TRIPS

S.S. "VIBEX."—Single-screw oil tanker, with accommodation for a small number of passengers, built and engined by Harland and Wolff, Ltd., Belfast, for Shell Tankers Ltd., London, E.C.3. Main dimensions: 635 ft. between perpendiculars by 84 ft. 3 in. by 46 ft. 3 in. to upper deck; deadweight capacity, about 31,000 tons. Double-reduction geared steam turbines, together developing 13,000 s.h.p. in service. Steam supplied by two water-tube oil-burning boilers, constructed by the shipbuilders. Launch, May 5.

M.S. "SUGAR IMPORTER."—Single-screw cargo vessel, built by Hall, Russell & Co., Ltd., Aberdeen, for Silvertown Services Ltd., London, E.C.3. Main dimensions: 330 ft. between perpendiculars by 50 ft. by 26 ft. 6 in.; deadweight capacity, about 5,250 tons on a draught of 22 ft. 2 in. Two eight-cylinder direct-reversing Diesel engines, together developing 3,040 b.h.p. at 300 r.p.m. in service, each engine being coupled through hydraulic couplings and reduction gearing to a single shaft running at 150 r.p.m. Engines constructed by British Polar Engines Ltd., Glasgow, and installed by the shipbuilders. Launch, May 5.

M.S. "THISTLEDHU."—Single-screw cargo vessel, built by John Crown and Sons, Ltd., Sunderland, for the Albyn Line Ltd., Sunderland. Main dimensions: 420 ft. between perpendiculars by 59 ft. 6 in. by 38 ft.; deadweight capacity, about 10,000 tons on a draught of 26 ft. Four-cylinder opposed-piston oil engine, constructed by William Doxford and Sons, Ltd., Sunderland. Service speed, 14 knots. Launch, May 6.

M.S. "DORINDA."—Single-screw trawler, built by Cochrane and Sons, Ltd., Selby, Yorkshire, for J. Marr and Son, Ltd., Fleetwood. Main dimensions: 127 ft. 6 in. between perpendiculars by 26 ft. 6 in. by 13 ft.; gross tonnage, about 335. Five-cylinder direct-reversing Diesel engine, developing 700 b.h.p. at 230 r.p.m. in service, constructed by British Polar Engines, Ltd., Glasgow, and installed by Amos and Smith Ltd., Hull. Launch, May 7.

H.M.S. "LEOPARD."—Anti-aircraft frigate, constructed at H.M. Dockyard, Portsmouth, for the Admiralty, London, S.W.1. Third vessel of a new class. Length, 340 ft. overall; beam, 40 ft. Armament comprises four 4·5-in. guns, two smaller guns and a "Squid" anti-submarine mortar. Admiralty standard range I-type heavy-oil engines, coupled to the propeller shafting through hydraulic couplings and oil-operated reverse and reduction gearboxes. Engines constructed by Vickers-Armstrongs Ltd., Barrow-in-Furness. Launch, May 23.

S.S. "POTOSI."—Single-screw cargo vessel, with accommodation for twelve passengers, built by the Greenock Dockyard Co., Ltd., Greenock, for the Pacific Steam Navigation Co., Liverpool. Third vessel of this type for these owners. Main dimensions: 476 ft. between perpendiculars by 66 ft. by 40 ft. 8 in.; gross tonnage, about 8,500; deadweight capacity, about 11,100 tons on a mean draught of 28 ft. Reaction steam turbines with double-reduction gearing, developing 9,400 s.h.p. at 108 r.p.m. in service, constructed by Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne. Steam supplied by two oil-fired water-tube boilers, constructed by Babcock and Wilcox, Ltd., London, E.C.4. Propelling machinery installed by John G. Kincaid & Co., Ltd., Greenock. Speed, 16½ knots in service. Trial trip, May 23 and 24.

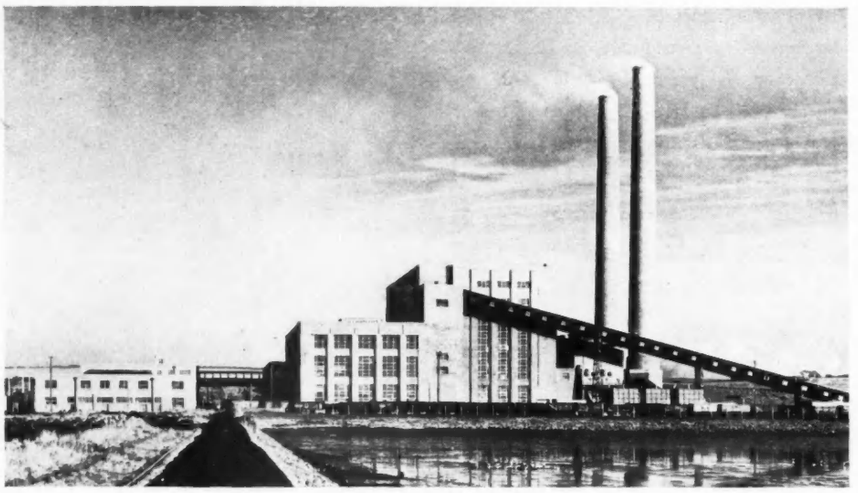


Fig. 1 Exterior of 120-MW power station at Roosecote, Barrow-in-Furness, from the west.

120-MW POWER STATION AT ROOSECOTE

CONSTRUCTION ON A RECLAIMED SITE

The Roosecote power station, near Barrow-in-Furness, in the North West, Merseyside and North Wales Division of the Central Electricity Authority has a present installed capacity of 120 MW and was originally envisaged by the Barrow-in-Furness Corporation. Messrs. Merz and McLellan, 32 Victoria-street, London, S.W.1. in association with James Williamson and Partners, 219 St. Vincent-street, Glasgow, C.2, for the civil engineering work and L. J. Couves and Partners, Carliol House, Newcastle-upon-Tyne, for the architecture and superstructure, were appointed consulting engineers. The first 30-MW set was commissioned in September, 1953.

CIVIL ENGINEERING WORK

The station, an external view of which from the west appears in Fig. 1 is constructed on a marsh which borders the sea and lies in the neighbourhood of Barrow dock. The site is about 110 acres in extent, of which 45 acres are available for ash and dust disposal, and it includes 40 acres of salt marsh 12 to 14 ft. above Ordnance Datum. This marsh land was built up to 20 ft. above Ordnance Datum by taking 250,000 cubic yards of fine sand from the higher parts of the area and thus forming a site for the main buildings and railway sidings. This work was carried out mainly by face shovels, though drag scrapers were used to some extent. The material was subsequently transported by lorries and bulldozed into position. An embankment for the ash settling ponds was formed in the same manner. The contractors for this part of the work were J. Gerrard and Sons, Limited, Swinton, Manchester.

Trial borings, conducted by Ground Explorations, Limited, indicated that the sub-strata consisted of layers of sand, gravel and clay with occasional boulders of hard rock. As this formation extended to a considerable depth, 4,220 reinforced-concrete piles, 16 in. in diameter and averaging 30 ft. long, were driven to support the foundations. These piles were manufactured on site by the Franki Compressed Pile Company, Limited, 39 Victoria-street, London, S.W.1. The foundations themselves, for the construction of which J. Gerrard and Sons, Limited, were also responsible, consist of reinforced-concrete blocks supported on the piling and carrying the columns, boilers and turbo-alternators. The reinforced-concrete culverts for the cooling water are carried on piles between these blocks, and elsewhere the concrete floor in the basements is supported on a reinforced-concrete raft.

The superstructure consists of a steel frame of plated box columns with slab bases, manufactured by Dorman, Long and Company, Middlesbrough, and is completed by brick cladding, the copings, sills, head and canopies being of artificial stone. The boiler house is 235 ft. long, 102 ft. wide and 116 ft. high, and the turbine hall 252 ft. long, 94 ft. wide and 68 ft. high. The latter is separated from the bunker bay by a brick wall to 8 ft. above the operating floor with glazing above. The main buildings are roofed with aluminium-alloy decking, while the floors consist of precast concrete units finished in terrazzo tiling or granolithic paving. The control room and administrative offices are in a separate building, which is connected to the operating floor of the turbine room by a bridge.

STEAM RAISING PLANT

The coal required for the station is entirely rail borne, unloading being effected by two side-discharge combined tipplers with a capacity of 25 tons. The coal is carried from the tippler hoppers either by a single belt conveyor to the boiler house where it is discharged to four 570-ton bunkers by a travelling tipper, or by a radial arm conveyor to a storage ground, the capacity of which is 67,000 tons when stacked to a height of 15 ft. The main contractors for the coal handling plant were Robert Dempster and Sons, Limited, Elland, Yorkshire.

The steam raising plant consists of four boilers, each with an output of 300,000 lb. of steam per hour at a pressure of 625 lb. per square inch and a temperature of 865 deg. F. The main contractors for these were Yarrow and Company, Limited, Scotstoun, Glasgow. Each boiler is independently supported from the main building superstructure and has two drums. The wall tubes, which are finned, have an outside diameter of 3½ in. The superheaters are of the self-draining Melesco type, while the Green economisers are of the welded double flow pattern, the air heaters being tubular. Pulverised fuel firing is used, there being three Lopulco mills to each boiler.

Forced draught on each boiler is provided by two single-inlet fans and induced draught by two double-inlet fans all with differential inlet control. There are also three exhauster fans, with paddle wheel impellers, on each boiler, which are driven by variable speed motors. All these fans were manufactured by Davidson and Company, Limited, Belfast.

Each boiler is controlled by pneumatic/hydraulic equipment provided by Electroflo Meters Company, Limited, Park Royal, London, N.W.10, the tilting burners being operated by apparatus manufactured by George Kent, Limited, Luton, which is actuated by the steam temperature.

DUST AND ASH DISPOSAL

The dust is removed from the flue gases by electrostatic precipitators installed by Lodge-Cottrell, Limited, George-street-parade, Birmingham, and, together with that from the chimney hoppers, is extracted under vacuum induced by water ejectors and discharged into the ash sluicing system. This system, the main contractors for which were B. V. C. Industrial Constructions, Limited, Grosvenor-gardens, London, S.W.1, comprises two high-pressure pumps, two clinker crushers and two ash pumps which deliver the slurry to storage ponds about 300 yd. from the boiler house. The ash and dust settles in these ponds, the clear water flowing over weirs to the station drainage system. The flue gases are discharged into two 300-ft. chimneys which were constructed on reinforced concrete foundations by P. C. Richardson and Company (Middlesbrough), Limited, Middlesbrough.

GENERATING PLANT

The generating plant of which an illustration is given in Fig. 2, consists of four Metropolitan-Vickers turbo-alternators with an output of 30 MW at 3,000 r.p.m. The turbines of these sets, which are supplied with steam at a pressure of 600 lb. per square inch and a temperature of 850 deg. F., are two-cylinder machines with 23 impulse stages in the high-pressure and six double-flow impulse stages in the low-pressure cylinder. They exhaust into three-pass two shell condensers, manufactured by Vickers-

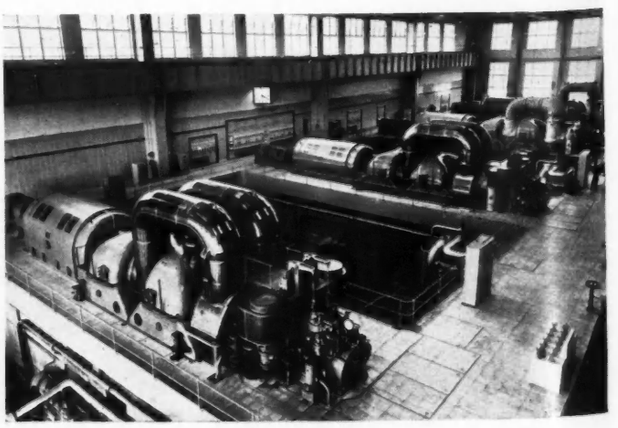


Fig. 2 The generating plant now installed consists of four 30-MW Metropolitan-Vickers turbo-alternators.

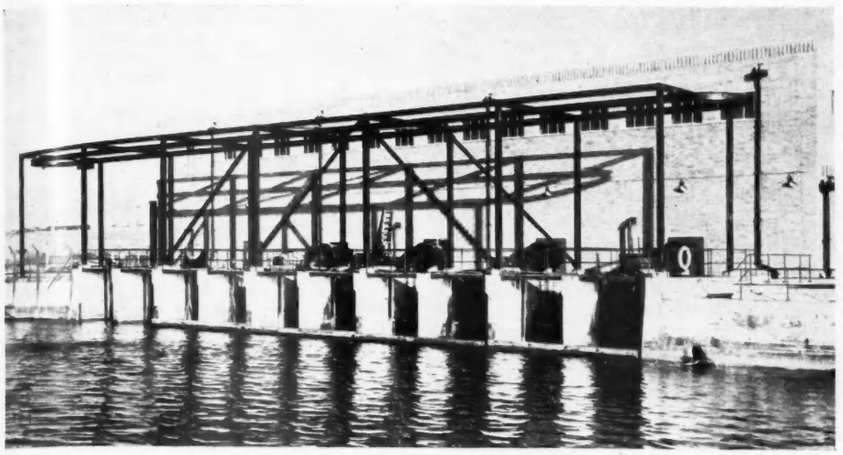


Fig. 3 Circulating water screens.

Armstrongs, Limited, Broadway, London, S.W.1, the design vacuum of which is 1·3 in. of mercury absolute when condensing 168,000 lb. of steam per hour; the inlet water temperature being 65 deg. F. and the outlet temperature 80·5 deg. F.

The condensate is extracted by two pumps for each machine, which were manufactured by Drysdale and Company, Limited, Yoker, Glasgow, W.4, and both of which are capable of handling the full quantity. The Weir air ejectors, of which there are also two per set, are of the steam-jet type and again each can handle the full capacity. They are fitted with a quick-start ejector which enables the rated vacuum to be raised in 20 minutes.

The feed-heating system, for which Vickers-Armstrongs Limited were the main contractors, consists of two low-pressure and two high-pressure feed-water heaters per machine, which are supplied with steam from the turbines at pressures of 3·62 lb. per square inch, 14·38 lb. per square inch, 47 lb. per square inch, and 157 lb. per square inch absolute, respectively. The station is equipped with six electrically-driven feed pumps, which were manufactured by the Harland Engineering Company, Limited, Alloa, and each of which is of 100 per cent. capacity. There are also four steam-driven pumps of 50 per cent. capacity, which are coupled to Mirrlees, Watson turbines.

Make-up feed water is obtained from the town's mains through a base exchange softener consisting of two units with a total capacity of 4,000 gallons per hour, whence is is pumped to the evaporators. This base exchange plant, which was manufactured by the Permutit Company, Limited, Gunnersbury-avenue, London, W.4, requires regeneration every 56,000 gallons, an operation which occupies about an hour. The central evaporating plant was supplied by Aiton and Company, Limited, Derby and the softened water pumps by Mather and Platt, Limited, Manchester 10.

Injection pumps enable chemicals to be supplied to each boiler drum as well as to each turbo-alternator unit for treatment after condensate.

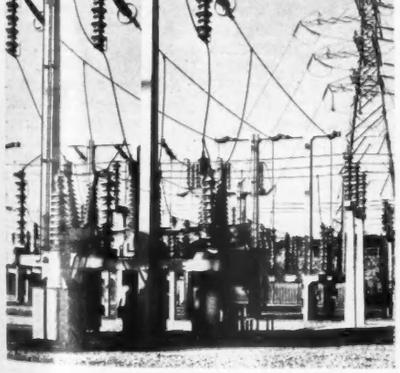


Fig. 4 Outdoor substation showing 132-kV switchgear.

CIRCULATING WATER SYSTEM

The cooling water for the condensers is drawn from the adjacent Cavendish Dock, a large expanse consisting mostly of sea water. This obviated the need for constructing elaborate civil engineering works on a sea shore which is composed of mud flats, and where the tidal range at springs is over 25 ft.

The pump house, which was built alongside the dock by Bierum and Partners, Limited, Harrow, Middlesex, contains four horizontal double suction centrifugal pumps, which were manufactured by W. H. Allen, Sons and Company, Limited, Bedford; each of them is capable of drawing 23,000 gallons per minute of water against a head of 40 ft., through screens manufactured by William E. Farrer, Limited, Hall Green, Birmingham, 28, which are illustrated in Fig. 3. Four bitumen-lined steel pipes, 60 in. in diameter, which are mounted on 14 in. by 14 in. precast reinforced-concrete piles, 30 ft. long, carry the water above ground across Salthouse Pool and are connected to underground reinforced-concrete culverts built into the station foundations. The water is treated by Wallace and Tiernan automatic intermittent chlorination plant with a capacity of 1,000 lb. of chlorine per 24 hours, injection being regulated by a clock.

ELECTRICAL EQUIPMENT

The turbo-alternators, which generate three-phase current at 11·8 kV and 50 cycles, are air-cooled by two fans on the rotor shaft, and each has a direct-driven exciter. They are solidly connected to 36-MVA, 11·8/132-kV transformers of Metropolitan-Vickers manufacture, which are fitted with on-load tap changing equipment. These transformers are installed in the switch compound, their high-tension sides being controlled by switchgear of the bulk-oil type with a rupturing capacity of 2,500 MVA, which was manufactured by Ferguson Pailin, Limited, Higher Openshaw, Manchester, 11. A view of this equipment is given in Fig. 4.

The generator and feeder circuit-breakers, the bus-bar couplers and bus section switch units are all connected to a double bus-bar system, as are the two 132/3·3-kV Metropolitan-Vickers station transformers.

The supplies for the station auxiliaries are obtained both from these station transformers and from four unit transformers, one of which is directly connected to each alternator. All these transformers are connected to 3·3-kV bus-bars from which the larger auxiliaries are directly supplied through air-break switchgear manufactured by the English Electric Company, Limited, Kingsway, London, W.C.2, and installed in annexes to the turbine room and boiler house. The smaller auxiliaries are supplied from other transformers at 415 volts through switch-fuses.

The control room contains a mimic diagram switchboard for the main transformers, outgoing 132-kV feeders, bus section switches and bus couplers, as well as a synchronising and a general purpose intaking panel. Immediately in front of it are four desk type generator control panels for the boiler and turbine house telephones.

The present Controller of the North West, Merseyside and North Wales Division is Mr. A. R. Cooper, while the Chief Generation Engineer (Construction) is Mr. C. R. Watson Smyth.

* * *

HIGH-ENERGY IGNITER PLUG

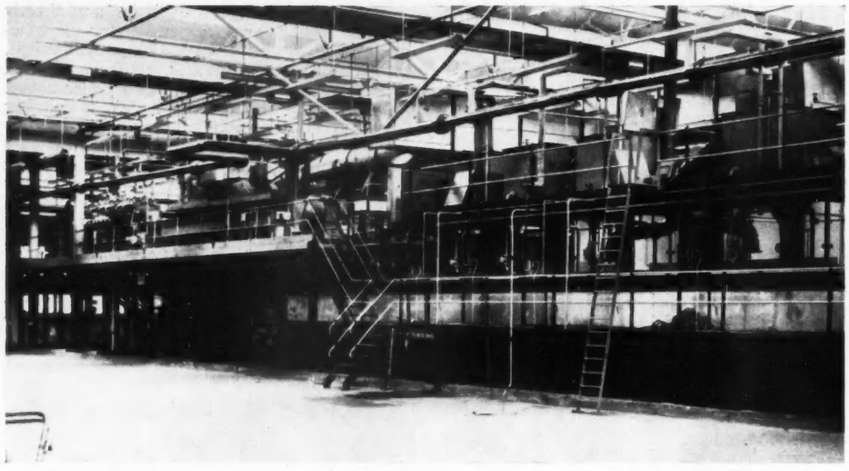
Starting Gas Turbines at Altitude

The high-energy igniter plug for gas turbines in aircraft, developed by K.L.G. Sparking Plugs, Limited, Putney Vale, London, S.W.15, was devised to overcome the disadvantages of the torch-igniter and booster-coil system of ignition, which was both sensitive to altitude and liable to spark-gap fouling through sooty deposits of the insulator. With the torch igniter, the electrical energy depends on the gas pressure in the vicinity of the electrode tip and earth wire, so that at some critical height the energy available for the arc decreased to such a low value that relighting of the engine was uncertain.

In the high-energy system, a higher electrical-energy source operating at a controlled break-down voltage ensures that a predetermined amount of electrical energy will be delivered to a special igniter plug regardless of external conditions. The high-energy plug itself is a " surface discharge " type instead of the conventional gap type. It consists of an inner electrode (live) and outer electrode (earth return), generally in the form of an annulus, separated by a ceramic tube. The firing end of the igniter has a semi-conductive coating " fired " on, ensuring the thermal, mechanical and electrical properties necessary for this system.

On receiving an initial electrical impulse from the high-energy unit a small path is ionised (through the carbon deposit if present) across the face of the semi-conductive ceramic. As this in turn has a negative temperature co-efficient, the resistance of the path immediately drops with increase in temperature and the whole mass of electrical energy stored in the high-energy unit is quickly dissipated in the form of an arc across the igniter face.

The high-energy plug, on the right, is free from the danger of spark-gap fouling; it operates in conjunction with a high-energy electrical source which is independent of altitude.



In addition to Courtaulds' very extensive laboratory facilities there is a pilot production plant in which viscose rayon staple can be manufactured under normal factory conditions.

LABORATORY FOR RESEARCH ON VISCOSE YARNS AND FIBRES

PROVIDING A WIDE RANGE OF SERVICES

Courtaulds Limited started the first commercially successful factory for the production of textile yarn by the viscose process at Coventry in 1905, and have since extended their manufacturing activities to other parts of the British Isles and overseas. Manufacturing is still carried on at Coventry and since the earliest days practically all the company's research on viscose has been concentrated in laboratories adjacent to the Coventry factory. In the period between the two world wars the viscose research laboratory developed progressively. As early as 1943, it was realised that the expansion of the man-made fibres industry in the post-war period was likely to be considerable, and that research facilities would have to be increased. A programme of research was therefore prepared, with the object of continuing the improvement of existing fibres, developing new manufacturing methods, and extending the search for new fibres. A major project in this programme was the new viscose research laboratory and its associated pilot plant, which have now been completed. The building and equipment were designed by the architects, service, electrical and instrument departments of the company's Engineering Division, under the direction of the chief engineer. The general contractors were W. H. Jones and Son, Limited, Coventry.

Viscose rayon, which in addition to its obvious applications in the textile trades, has many industrial uses such as reinforcement for automobile tyres, colliery conveyor belting and power transmission belting, is basically pure cellulose. The principal raw material is highly-refined wood pulp, which is converted by a series of chemical processes into cellulose xanthate. This is dissolved in dilute alkali to form viscose, which is extruded through spinnerets into an acid bath, where it coagulates and is changed back to pure cellulose in fibrous form. The basic principles of viscose rayon manufacture are therefore the concern of the chemist rather than the engineer, but the equipment used in the manufacture, examination and testing of the finished product involves the solution of many engineering problems. In the design and equipment of the research laboratory the co-operation of the engineers with the other departments concerned has resulted in a particularly fine building which is eminently functional and at the same time handsome in appearance and pleasant to work in.

The laboratory is housed in a completely new building erected on a site formerly occupied by a mill which was destroyed by bombing in 1940 and 1941. It adjoins an existing block of buildings to which it is connected by an office wing. There are four storeys and a basement in the laboratory proper, and separate laboratories are provided for the examination and testing of wood pulp, viscose and textiles. Other self-contained rooms house physics, physical chemistry, organic chemistry, photography and microscopy, mass pigmentation, textile service, analytical, tyre-cord testing and spinning research laboratories. Facilities are also provided for glass blowing, for the supply and maintenance of laboratory equipment, the development of engineering equipment to place new processes on a sound operational basis, and for the production of viscose rayon yarn in pilot plants. For this latter purpose there are pilot plants of the laboratory type, with small outputs, and a larger plant which will produce up to 20 tons of viscose rayon staple per week. In this plant, illustrated above, it is possible to reproduce normal manufacturing conditions. For pilot production of yarn there is a continuous spinning machine which has an output of up to 15,000 lb. of yarn per week.

LABORATORY LAYOUT

The general plan is that of a rectangular block, with a central corridor and laboratories on each side. Vertical ducts are provided for the main services. The laboratories proper are built up from a standard module of 25 ft. 6 in. by 11 ft. 9 in., each module being fully serviced so that the internal layout and sub-division of the floor areas can be modified as required. A large entrance hall is situated on the ground floor and the laboratories occupy the major part of that floor and the three floors above. A statistics office is housed on the second floor, and a library occupies the end of the office wing on the third floor. Staircases, lifts and cloak-rooms are grouped together at each end of the central corridor. The basement houses the air conditioning plant and switchgear, general stores, glass-blowing room and a special laboratory for tyre-cord fatigue testing.

The office wing, which connects the laboratory to the older buildings, is at right angles to, and at one end of, the laboratory block. It is of three storeys only, the lower storey being omitted to form an entrance bridge leading to an internal courtyard. In this wing the corridors on each floor are at the side, where they abut on a busy main road, leaving the offices on the quiet side facing the courtyard.

The laboratory building is steel-framed with floors and roof of pre-cast concrete. Facings are different on two elevations. On the side abutting on the public highway " Cotswold grey " facing bricks have been used, and the elevation has been designed to have about the same solid to void proportions as the older building it adjoins. This elevation is plain in appearance, but is relieved by the light and open treatment of the wrought iron and bronze entrance gates under the bridge formed by the office wing. On the courtyard side of the laboratory block the elevation is mainly of glass, double glazing being employed throughout.

SERVICE REQUIREMENTS

The comprehensive nature of the laboratories calls for a particularly extensive range of services. Provision is made throughout the building for supplying high and low pressure steam, with condensate return; water for laboratory use, flushing valves and drinking and domestic purposes; soft, demineralised and hot water; compressed air for general service, with a separate circuit for instruments; vacuum; town gas; and cooling brine. The services are distributed by header mains running through the basement at high level, with branches rising to vertical distribution ducts on each side of the central corridors. Branch pipes from these risers pass through shallow ducts on each floor to the island benches in the laboratories. The floor ducts continue to the outside wall, pass underneath the wall benches and return alongside a similar duct in the next module. By this arrangement it is possible to provide piped services to benches in any position in the module, and the necessity for exceptionally wide trenches under the windows is obviated. There are isolating valves on the incoming mains, at the bottom of each riser, and on the branch mains.

STEAM AND WATER SUPPLIES

Steam is brought from the adjacent factory through a 6-in. diameter main at 25 lb. per square inch and a 1½ in. diameter main at 175 lb. per square inch. The high-pressure main runs through the basement corridor and rises into a small plant room on the first floor. Low-pressure steam is taken to the various heaters for the air-conditioning plants, heating and hot-water service calorifiers and steam-usage points. Steam traps are provided on the heaters, calorifiers and main trench points, and the condensate is led to a collecting tank in the basement, whence it is pumped to the factory boiler house.

Water for general laboratory service is taken from Coventry City mains, and metered to a 3,600-gallon storage tank on the roof. A 4-in. diameter service main runs down from this tank to the basement plant room, where booster pumps ensure that a pressure of at least 30 lb. per square inch is available. This arrangement of the general water supply makes the water suitable for a range of cooling work, as it has a maximum temperature of about 60 deg. F. A separate branch connection is taken from the City mains for supplying drinking water, and a tank in the tank room on the roof provides water for the automatic flushing valves of the lavatories. Soft water is taken from the factory mains, and hot water is supplied by a copper storage calorifier in the basement, with a gravity circulating system. Demineralised water for special purposes is provided by a treatment plant in the basement, which draws its water from the City mains.

COMPRESSED AIR AND VACUUM

Two compressed air services are provided for the laboratories, with a separate supply at 10 lb. per square inch for the glass-blowing room. A clean-air compressor in the basement delivers 188 cub. ft. of free air per minute at 30 lb. per square inch for general use. It is driven by a

40-h.p. electric motor and draws its air from outside the building. Water from the City mains is used for cooling. A standby supply in case of compressor failure can be drawn from the factory mains through filters.

For instrument use the air is compressed to 40 lb. per square inch in a separate compressor, which is also housed in the basement plant room. It is of the rotary water-sealed type drawing its air from outside the building, and delivers 30 cub. ft. of free air per minute. The compressor is driven by a 10-h.p. electric motor. A large receiver is provided to ensure constant pressure. The air is dried by passing it through an automatic air drier of the "Humidifier" type with two drying cells, one being in use while the other is being regenerated. The automatic changeover gear enables the equipment to be used without manual attention. As a standby the air receiver of the dry-air compressor is cross-coupled to the receiver of the general air supply.

A rough vacuum system is provided for filtration and similar purposes throughout the laboratory building by means of a vacuum pump in the basement plant room. The pump has a rated capacity of 100 cub. ft. per minute at 24 in. of mercury and is driven by a 10-h.p. electric motor. The system is provided with a trap tank in the basement to prevent damage to the pump should any harmful material be drawn into the pipeline. The vacuum is held at a constant value by an automatic regulator with a widely-variable setting.

MISCELLANEOUS SERVICES

Town gas is piped to all benches, fume cupboards and apparatus racks. Check valves are provided on the benches to prevent contamination of the gas distribution system through breakage or misuse of experimental apparatus.

A brine circulating service is brought from the factory refrigeration plant for the air-conditioning systems, and it is also connected to certain points in the laboratory. The brine temperature is approximately 20 deg. F.

Control of the services on the benches is through gunmetal fittings with needle valves, operated by handles on extended spindles at the front of the benches. Each handle is of a distinctive shape according to the service it controls, and identification of the individual services is further assisted by a uniform colour code for the controls. The arrangements at the fume cupboards are similar to those at the benches.

Emergency water showers have been fitted on the wall of each laboratory next to the fume cupboard, and close to each shower is an alarm push-button which operates a red light in the corridor over the door concerned. It also sounds an alarm on the same floor and operates an indicator and alarm in two other places.

HEATING, VENTILATING AND AIR CONDITIONING

The general heating and ventilating is by a plenum system which is divided into three zones for each floor, each zone being under separate control by means of pneumatically-operated indicating controllers to allow for the different fabric heat losses. Air distribution is through branch ducts formed by encasing the floor beams at ceiling level. The air discharge grilles give horizontal and vertical control over air direction. The main delivery ducts run in the false ceiling space over the corridors and the zone heaters are fitted to the branches off the main rising air shaft.

A spray-type humidifier in the basement plant room gives up to 50 per cent. relative humidity during the lowest outside winter conditions, and there is a pre-filter of the oil-coated type. For heating the full air volume to 60 to 65 deg. F. there is a main heater installed after the humidifier. The humidifier also gives some degree of cooling in hot weather. No recirculation of air is provided for in the chemical laboratories.

Part of the laboratory requires constant air conditions of 68 deg. F. and 65 per cent. relative humidity. This area is served by a separate plant, comprising a spray-type air conditioner, the water for which can be either steam heated or brine cooled. Recirculation in this area is permissible, since the work done does not produce any noxious or objectionable fumes, and fresh air is admitted only in sufficient quantity to ensure adequate ventilation. A further separate air conditioning plant serves a small laboratory in which air conditions can be varied between 50 deg. F. and 90 deg. F., and 25 per cent. and 90 per cent. relative humidity at any dry-bulb temperature in the range mentioned.

The fume cupboards are each connected to a separate fan, and these units are in operation during normal working hours, as their extraction rates are included in the planned air-change rates for each section of the laboratory.

ELECTRICAL EQUIPMENT

A 415-volt, three-phase, four-wire, 50-cycle electric supply is brought from the factory power station to a main fuse-switch type distribution board housed in a separate room in the basement. Supplies are drawn from this point through fuse-boards feeding ten sets of vertical rising mains consisting of 100-ampere VRI cables carried in hard-wood clamps in steel trunking which runs in the service ducts. Tappings are taken from the rising mains to separate lighting and power distribution fuse-boards with high-rupturing capacity cartridge fuses. Provision has been made for any main to be tapped at any floor level as required. From the fuse-boards, lead-covered VRI cables are taken in floor ducts with removable covers to feed-outlet sockets, of which there are about 1,000, mounted along the backs or centres of the benches. The loading factor is low, and up to ten sockets can be connected to 240-volt spur circuits; 13-ampere fused plugs with switched sockets are used.

The general lighting in the laboratories is of the fluorescent type, giving an intensity of 30 lumens per square foot at the working surfaces. Filament lighting is used on the staircases and in the office wing.

An electronic instrument designed to indicate the commencement of any phenomenon which causes vibration. Developed initially for indicating the moment of contact of a grinding wheel and work-piece.

When a number of small packets have to be carried on a fork-lift truck they can be steadied by the clamping device shown here. It is operated hydraulically.

TRANSPORTING LOOSE PACKAGES

Hydraulic Clamping Device for Fork-Lift Truck

One of the problems connected with the transport by fork truck of a number of separate items such as tins, small boxes and the like, has been the steadying of the load when traversing uneven ground. To combat this, I.T.D. Limited, 95-99 Ladbroke-grove, London, W.11, have developed the clamping device shown in the illustration above. The device can be fitted to any of the firm's Stacatrucs, on which it replaces the standard backguard.

The hydraulic cylinder which operates the clamp is mounted in the projecting bracket (the flexible connections can be seen in the illustration) together with the clamping-lever pivots. Operation of the ram raises or lowers the lever which, at its outer end, has a clamping plate attached. The double action is controlled by a two-way valve near the driver's hand. In this way, the packages are gripped lightly between the plate and the forks, giving the necessary stability to the load. The plate can, of course, be altered in shape to suit the load being carried.

* * *

PRECISION GRINDING

Determining the Moment of Contact

During the grinding of metal, much heat is generated. Therefore a cooling liquid is pumped over the wheel and work to prevent the ill-effects which might result. However, the presence of the coolant prevents the operator from being able to determine, either by sight or sound, the exact moment when the work touches the wheel. This leads to the risk of removing too much metal inadvertently.

To overcome this difficulty in grinding, B. O. Morris, Limited, Briton-road, Coventry, have developed an electronic device which gives an indication on a cathode-ray tube directly the work makes contact with the wheel. A vibration pick-up is mounted on the grinder which immediately detects the beginning of any grinding vibrations and causes the trace of the tube to take up a V-shape. The apparatus, which is shown in the accompanying illustration, measures 6 in. by 4½ in. by 13½ in. and weighs 12 lb. The pick-up responds to any frequency between 4 and 30 kilocycles per second and the use of the equipment is by no means limited to grinding. It can be used in any process where it is required to detect vibration. One suggestion given is for detecting break-through when drilling deep intercepting oil holes; another is for checking bearing condition, giving warning of any impending failure.

ELECTRICITY SUPPLY IN LONDON*

RATIONALISING OPERATION, EQUIPMENT AND TARIFFS

By D. B. Irving, B.SC.†

The London Division of the Central Electricity Authority operates 28 power stations with an aggregate capacity of over 3,250 MW and ranging in size from Barking (750 MW) to Shorts Gardens in the West End (3 MW). The latter is the sole remaining example of internal-combustion plant on public supply in the area and is the only one generating at the utilisation voltage of 210 volts. It is a direct-current station and makes a welcome contribution to peak loads. Other generation voltages range from 5·2 kV at St. Pancras to 33 kV at Taylor's Lane, Willesden.

HIGH-VOLTAGE SYSTEMS

The high-voltage systems of the London Board consist entirely of underground networks operating at 66 kV, 33 kV and 22 kV. Before Vesting Day the growth of demand caused the London Power Company to run transmission circuits eastwards on a large scale from Battersea and the County of London Company to do the same westwards from Barking. Had the same operating voltages been adopted the marrying of the systems after nationalisation would have been simplified. It was, however, fortunate that the communication circuits of the London Power Company could readily be diverted into the County Company's control centre at Streatham, which has become London Distribution Control.

After the 1939–45 war, the growth of load rendered the reinforcement of bulk supplies at many points urgent and it was necessary to construct these concurrently with the formulation of long-term plans. One of the cardinal principles on which these long term-plans are founded is the reduction to a minimum of the distances over which bulk supplies are transmitted within the area. This principle has also been borne in mind in considering urgent short-term schemes. It will not, however, be possible to attain the ideal transmission system since it is necessary to utilise to the full, within economic limits, the equipment inherited by the Board at Vesting Day. Nevertheless, substantial savings have been made on the expenditure which would have been necessary under pre-nationalisation arrangements.

For instance, a new 66 kV substation in south-west London with an installed capacity of 150 MVA is supplied from a power station some 8 miles nearer to it than would have been possible on Vesting Day. The result has been a saving of £750,000 on 66 kV cables and a recurring saving of some £35,000 per annum on transmission losses. One of the features of the Board's plans is the extended use of extra high voltage transformer feeder circuits to economise in the use of switchgear.

SUBSTATION EQUIPMENT

Voltage reduction from 66 kV is effected at seven major substations with a total installed capacity of 500 MVA, the sizes of the individual transformers ranging from 15 to 50 MVA. These stations in turn feed 72 main substations at either 33 kV or 22 kV with a total capacity of 2,264 MVA, in which the sizes of the individual transformers range from 3 to 20 MVA. In addition, there are 7,128 local substations with a transformer capacity of 3,536 MVA for reducing the voltage to supply the medium and low voltage networks. At some of these single-phase and two-phase supplies are given from Scott-connected transformers and at others direct-current is furnished by rotary plant and rectifiers. The rupturing capacities of the switchgear in these stations range from 1,500 MVA at 66 kV to 150 MVA at 11 kV. These ratings are governed largely by the presence in the system of switchgear which it would be uneconomic to replace. On the standard 415/240 networks the maximum value of the short-circuit duty is 25 MVA.

The return of evacuated population and the recovery of industrial activity after the war accentuated the need for replacement of obsolete distribution and the reinforcement of the more modern standard systems. It was therefore decided to regrade the cables in certain districts from 5·2 kV and 6·6 kV to 11 kV and from 3·8 kV and 5·2 kV to 6·6 kV. Some gloomy forebodings concerning the vulnerability of joints have so far been unfounded and paper-insulated lead-covered cables properly installed have proved themselves to be the most reliable of all items of electrical plant.

Although standardisation is proceeding the maximum demand carried by the Board's systems in 1954 still included components of direct-current (8·9 per cent.), two-phase alternating current (2·2 per cent.) and other non-standard alternating current (22·7 per cent.). The Board has 170,000 consumers on direct-current and 627,000 on non-standard alternating current supplies. It is estimated that the total cost of change-over at present prices will be about £50 million. During 1953–54, 37,000 consumers were changed to standard supplies.

POLICY OF RATIONALISATION

The Board's policy of rationalisation is founded on that described by Leach* for the City and West End in 1941. It consists of unit areas based on bulk supply points of 48 MVA capacity fed at 22 kV and higher voltages. The typical bulk supply point was designed for an ultimate installation of four 12-MVA transformers feeding up to four sections of 11-kV bus-bar, normally operated singly or in pairs. The high-voltage feeders were laid out as ring mains, but operated as radial feeders, thus permitting the use of simple over-current and earth-fault protection. The low-voltage distributors were uniform in section and were laid along each side of the street. The low-voltage network was interconnected solidly in sections corresponding to the high-voltage feeders and by fuses over a district corresponding to 12 MW. Four such self-contained districts comprised a 48-MW unit, all on a basis of 25 per cent. or less spare capacity.

The 500-kVA transformer chambers, situated mainly in consumers' premises, were equipped with high-voltage ring main units with an automatic oil circuit-breaker in the tie, and with over-current and earth-fault protection for the transformers. Between the low-voltage side of the transformer and the interconnected low-voltage network was an air circuit-breaker fitted with oil time-delayed over-current protection and intertripping. The arrangement reaps great advantage from diversity of demand with minimum losses and affords high continuity of supply, owing to the stand-by provided by the low-voltage network interconnection in event of the failure of the high-voltage feeders or local transformers.

AN "INTERLEAVED" SYSTEM

In another system† of supplying an interconnected low-voltage network the high-voltage switchgear is simplified by the omission of the automatic oil circuit-breaker and the use of a plain tie connection to the purely radial high-voltage feeder. The distribution transformers are "interleaved" and the network protection between the low-voltage side of the transformer and the low-voltage network is motor-operated, control being by a combined reverse-power and auto-closing relay. The arrangement offers an opportunity for considerable economy where outdoor construction can be made to fit with the amenity requirements of planning authorities. These solid systems, however, have a proper economic application only in cities where the load and consumer density are high. In parts of the City of London the load density is already in excess of 100 MW per square mile and is expected to approach 200 MW per square mile within the next 15 years.

As regards standardisation, the Board decided upon the distributed-transformer system with a standard transformer capacity of 500 kVA, and extensions were required to make provision for ultimate developments on those lines. A limited range of standard cable sizes and a standard range of meters were also adopted. In the larger substations the trend towards eliminating continuous attendance has made it desirable to provide more automatic features for the operation of the main transformers. The typical size of these is now 15 MVA with sufficient reactance to retain general fault levels in the 11-kV distribution systems at 150 MVA or in special cases up to 250 MVA. Four types of standard services have also been devised and there has been much detailed standardisation of individual items of stores and equipment. Further, the procedure for connection, disconnection and supply of energy to consumers' installations has been standardised, stress being laid on inspection and testing.

ADMINISTRATIVE ARRANGEMENTS

For administrative purposes Engineering Headquarters has direct responsibility for all work associated with the 22 kV to 66 kV transmission

Fig. 1 Maximum demand, actual and estimated, (1926-70) and electricity sold (1935-36 to 1952-53) in the area of the London Electricity Board.

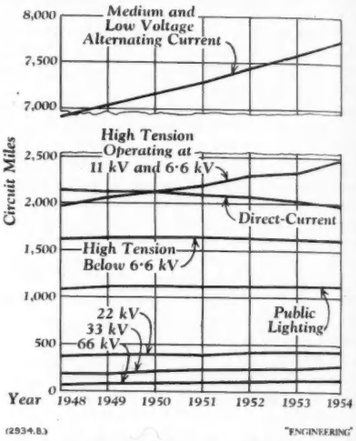


Fig. 2 Lengths of cables installed in the area served by the London Electricity Board.

* Paper entitled "The Supply of Electricity in the London Area," read before the Supply Section of the Institution of Electrical Engineers on Wednesday, May 18. Abridged.

† Mr. Irving is with the London Electricity Board.

* J. W. Leach, "Standardisation of Distribution in Densely Loaded Areas." *Journal of the Institution of Electrical Engineers*, vol. 88, Part II, page 171 (1941).

† C. R. Webb, *Proceedings Institution of Electrical Engineers*, vol. 98, Part II, page 344 (1951).

systems and bulk supply points, while the Sub-Areas and Districts are responsible for the distribution systems operating at 11 kV and lower voltages. The main commercial problem confronting the Board at Vesting Day was that of tariff standardisation, there being no fewer than 270 different rates for electricity supplies. The policy has been to proceed by gradual steps towards ultimate tariff standardisation and the result has been a flat rate of 5*d.* per unit for lighting and 1¾*d.* per unit for power. Two-part rates are not yet fully standardised but steps have been taken to adjust the monetary values in the different forms of tariff so as to bring about, as closely as practicable, equivalent charges for equivalent services.

MAXIMUM DEMAND AND UNITS SOLD

Fig. 1 shows the aggregate maximum demands, actual and estimated, of public electricity in the area of the London Board from 1926 to 1970, and the units sold from 1935-36 to 1952-53. Fig. 2 shows the length in circuit-miles of cables installed, giving the cumulative totals at and since Vesting Day.

Some 24 per cent. of all the faults which have occurred since Vesting Day have been due to external agencies, such as mechanical damage, fire, flood, vermin and incidents on consumers' installations. A relatively large number of faults have occurred on medium-voltage cables in certain districts, owing to the continuance in service of old distribution networks. Regarding the higher-voltage systems at 66 kV, faults have occurred at the rate of about one per annum per 100 circuit miles. On the 33 kV and 22 kV cable systems taken together the equivalent assessment is 1·6 faults per annum per 100 circuit miles. The majority of faults have been in joints. The 11 kV and 6·6 kV cable systems are subject to much mechanical damage by reason of their extent and of the difficulties of adequately protecting them in parts of London. The assessment of faults on these systems is, however, only 0·5 fault per annum per 100 circuit miles due to mechanical damage and a similar rate due to failures in joints and terminations.

As a result of unification it has been possible to effect considerable savings, which have offset in no small measure the annual increases in the cost of labour and materials. The average rate of growth of maximum demand in the Area is about 100 MW per annum and when wartime arrears of transmission construction work have been overtaken it would be possible, apart from the replacement of non-standard equipment, to settle down to a consistent rate of reinforcement equivalent to about two or three main supply points each year. In the past five years it has been necessary to build at double this rate.

There is no indication that a saturation of demand is in sight and Fig. 1 suggests that in 1970 the maximum demand will be about 3,250 MW. The author considers himself justified in accepting this conclusion by the knowledge that the annual consumption in the Area is as great as that given in the Electricity Commissioners' returns for the whole of Great Britain in the year (1926) which saw the creation of the Central Electricity Board.

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RELAY WITH MOULDED BODY

A relay recently introduced by Londex Limited, 207, Anerley-road, London, S.E.20, has the body made of a moulding which allows the sections carrying the contact terminals to be removed without disturbing the relay adjustment. Panel fixing is by two 4 B.A. screws. The operating coil can be supplied for any voltage up to 450 alternating-current or 165 volts direct-current. Power-consumption is between 1 and 3 watts. A variety of contact arrangements is available: there may be from one to five sets of "make" or up to three sets of "break" or "changeover." The standard contacts, of 6-mm. solid silver, are rated at 5 amp. at 230 volts, alternating current. Overall dimensions of the relay are 3⅝ in. by by 1⅞ in. by ⅞ in.

Labour Notes

THE RAILWAY STRIKE

Much to the dismay of millions of ordinary folk in all parts of the country, the strike of 70,000 members of the Associated Society of Locomotive Engineers and Firemen became an accomplished and unwelcome fact at midnight on Saturday last, May 28. Among the hardest hit are the people who travel by train to and from their work or place of business. For many generations it has been the custom of millions of people to live in "dormitory suburbs" from which they travel by train into the towns and when there is an interruption or a material diminution of the railway service, chaos ensues. The consequences were outlined by the Prime Minister in a broadcast from Chequers on Sunday. In telling sentences he stated that, whatever happened, the country would be hurt and that the damage which must be caused would injure our nation in a world which was becoming increasingly competitive. Supplies to factories would be affected at once and this must bring unemployment on a rapidly increasing scale to persons in no way involved in this dispute.

Already, on Tuesday morning, there were reports from various centres of the possibility that many steelworks employees may be thrown out of work unless the strike is settled quickly. At the time of writing there are no indications of any end to the stoppage and it is foreshadowed that the Government may seek special prerogatives under the Emergency Powers Act of 1920.

THE DOCK STRIKE

The strike of dock workers on Merseyside, Manchester, Hull and London called by the National Amalgamated Stevedores and Dockers for Monday, May 23, is now in its second week. Over 18,000 men were idle all last week, while 30,000 have continued to work, with the result that out of some 300 ships at these ports only about a third are being worked normally, another third are undermanned and the remaining third are idle.

As is now well known, the strike was organised in support of a claim for the recognition of the N.A.S.D. as a fully-negotiating body, in addition to the Transport and General Workers' Union, in the dock industry at Liverpool and Birkenhead, Manchester and Hull. The N.A.S.D. is already so recognised in London.

Numerous conferences have been held and there has been much talk of "frank exchanges of views" but little material progress appears to have been made so far.

PERCENTAGE PAYMENTS ON GROSS WAGES OF DOCKERS

The National Dock Labour Board, 9 and 10 Upper Brook-street, London, W.1, has reviewed its financial position in the light of current and future trade prospects and of the increases in firstly, the rates of attendance money and guaranteed weekly payments operative from January 10, 1955; secondly, the rates of wages operative, in the main, from April 16, 1955; and, thirdly, National Insurance contributions due to come into force on June 6, 1955. The Board has also had regard to the strength of the reserves now held for levy stabilisation, and to its previous statement to the industry that a policy of stability does not preclude "adjustments in either direction to take account of changes which affect the average income or expenditure" on which the levy is based.

The Board has, therefore, decided that the rates of percentage payments should be adjusted to an extent which, on average and according to the best estimates at present available, is expected to offset the additional net income which would otherwise accrue from the changes noted above and from the closer regulation of manpower.

Accordingly the Board has given notice under Clause 21 (1) of the Dock Workers (Regulation of Employment) Scheme, 1947, that, as from the normal finishing time on Saturday, July 2, 1955, the rates of percentage payments on the gross wages of registered dock employees will be reduced as follows: for daily employees engaged on work other than coastal traffic, from 14½ to 13 per cent.; for daily employees engaged on coastal traffic, from 10½ to 9 per cent.; and for weekly employees engaged on coastal or other work, from 4½ to 4 per cent.

THE B.B.C. AND THE ELECTRICAL TRADES UNION

Under an agreement signed recently the British Broadcasting Corporation have recognised the Electrical Trades Union as a negotiating body, in addition to the B.B.C. Staff Association, on staff matters in respect of all categories of electricians and their assistants employed by the Corporation. The recognition of the Electrical Trades Union follows the acceptance, by the union, of recommendation 93 of the Report of the Broadcasting Committee, 1949 (the Beveridge Report) so far as the B.B.C. staff are concerned, and the demonstration, by the E.T.U., that it has a substantial membership serving on the agreed categories of staff. Among other things, the agreement signed by the Electrical Trades Union and the Corporation provides for the E.T.U., the B.B.C. Staff Association, and any other unions similarly recognised by the Corporation, to work together.

INTERNATIONAL LABOUR CONFERENCE

The 38th session of the International Labour Conference opened in Geneva on June 1 and is expected to continue until June 23. A tripartite delegation from the United Kingdom is attending the conference. The Government delegates are Sir Guildhaume Myrddin-Evans, K.C.M.G., C.B., deputy secretary of the Ministry of Labour and National Service, and United Kingdom representative on the Governing Body of the International Labour Office, and Mr. A. F. Harrison, C.B.E., solicitor, Ministry of Labour and National Service, with Mr. G. C. Veysey, C.B., under-secretary of the Ministry as substitute delegate. The Employers' delegate will be Sir Richard Snedden, C.B.E., chairman of the International Standing Committee and member of the general purposes committee and of the Council of the British Employers' Confederation, and member of the Governing Body of the I.L.O. The employees' delegate will be Sir Alfred Roberts, C.B.E., member of the Trades Union Congress General Council and also member of the Governing Body of the I.L.O.

The agenda of the conference provides for a second discussion on each of three items which were the subject of first discussion at the last session of the conference, namely, vocational rehabilitation of the disabled, migrant workpeople (under-developed centres), and penal sanctions for breaches of contract of employment. The agenda also provides for a first discussion on two new items, namely, vocational training in agriculture and welfare facilities.

COLLIERY MANPOWER AND PRODUCTIVITY

A statement issued by the Ministry of Fuel and Power, Thames House South, Millbank, London, S.W.1, shows that the output of deep-mined and opencast coal during the first 20 weeks of the present year totalled 87,905,700 tons, compared with 90,224,000 tons during the corresponding period last year. The tonnage of deep-mined coal lost through disputes is placed at 1,840,800 tons up till May 21 this year, against 622,400 tons in the period January 1 to May 22, 1954. The average weekly number of men on the colliery books during the first 19 weeks of 1955 was 708,200, of whom 290,500 were face workers. Corresponding figures for the first 19 weeks of 1954 were 709,200 and 291,500 face workers. The average weekly number of shifts worked per wage-earner was 4·82 this year against 4·89 last year, but the output per man-shift at the face has averaged 3·268 tons this year, as compared with 3·258 tons in 1954.

PHOTOGRAPHIC COPYING PROCESS

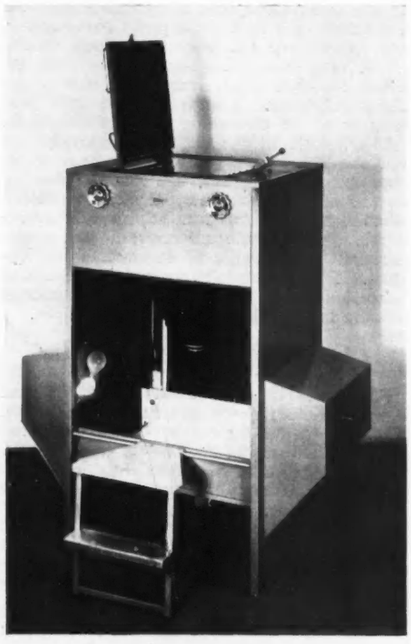
Reduced or Enlarged Reproductions of Print, Drawings or Photographs

A process which enables written or printed matter, drawings or photographs to be reproduced on a stencil for duplication within a few minutes has been developed by Gestetner, Limited, Aldwych House, London, W.C.2. Known as the "Reduction Photoscope," it combines photographic and stencil duplicating techniques, and can produce reduced or enlarged copies of the original subject as required. Engineering drawings or data sheets can be conveniently reproduced by this means for storage or distribution.

The unit, as can be seen in the accompanying illustration, consists of a cabinet containing a vertically adjustable table, on which the original material is secured by a glass plate. Illumination is provided by four 500-watt long-life lamps backed by reflectors, and an image is formed by a photographic lens situated above the table. A removable ground-glass plate marked out in standard areas and located in a chamber at the top of the cabinet provides a focussing screen and enables the lens and the table to be adjusted by means of two hand controls to give a clear image of the required size. After removal of the ground-glass screen, the photographic stencil is inserted—together with a half-tone screen if the original subject is a photograph—and an exposure made. After development, washing and drying, the stencil is ready for use. In effect, the chemical image on the stencil serves as a negative mask so that ink can only penetrate in areas corresponding to the dark parts of the original.

An automatically-operated vacuum blanket fitted to the exposure frame ensures good contact between the stencil and the image plane. Exposure times vary between one and three minutes, according to the nature of the original material. Simple counterbalance controls have been fitted for altering the distance between copy-holder and lens, and the holder can accommodate anything from a single sheet of paper to a book 1¼ in. thick. Guide sheets enable the originals to be located quickly and easily.

The Photoscope, which is constructed in steel, stands 6 ft. 9 in. high and occupies an area of 6 ft. by 4 ft. The full ratio of reduction or enlargement is 1·8 to 1, and enlargement in proportion can be made up to a maximum of 16½ in. by 13 in. The copy holder accommodates originals up to 22¾ in. by 29¼ in. in size, although the maximum printing area is only 20⅜ in. by 16½ in. Originals of this size can be reduced for printing on 16½-in. by 13-in. paper, and reproduced on Gestetner 280 series machines. Originals, 13½-in. by 22½-in., can be reproduced on 8¼-in. by 13-in. paper by means of Gestetner 260 series machines.



By means of the Gestetner "Reduction Photoscope," engineering drawings, data sheets, printed matter or photographs may be reproduced on a stencil for duplication, within a few minutes. The maximum ratio of reduction or enlargement is 1·8 to 1.

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CONVERTIBLE SEAM WELDER

Machine for Both Longitudinal and Circumferential Work

The range of resistance welding equipment being made by Philips Electrical, Limited, Century House, Shaftesbury-avenue, London, W.C.2, has been increased by the addition of a universal seam welder for making both longitudinal and circumferential seams. Several models are made in this, the ES. 2003, series, with outputs ranging from 75 kVA to 200 kVA and throat depths of 24 in., 32 in. and 42 in. The machines can handle mild steel and most refractory alloys up to two thicknesses of 14 s.w.g. material. The illustration shows a model with a 42-in. throat set up for longitudinal welding of tubes.

Conversion from longitudinal to circumferential welding is simply accomplished. The upper wheel assembly is rotated through 90 deg. and the lower assembly replaced. In both arrangements, current is supplied to the lower wheel through a segmental commutator; this allows non-conducting needle-roller bearings to be used, giving an increased bearing life. The upper wheel is driven by a three-phase motor and can be adjusted to give any speed between 3 and 15 ft. per minute, in either direction.

Vertical adjustment of the lower arm is carried out by means of a hydraulic jack, giving a maximum variation of 9 in. Standard machines can take work down to 7¾ in. in diameter; smaller sizes require special arrangements. Welding pressure is supplied by an air cylinder which incorporates an interlocking switch to prevent the commencement of a weld before full pressure has been applied; auxiliary equipment is fitted to clean and dry the air used. The machine is designed to operate under the control of a Philips "Tempomat" unit, which is used to both time and regulate the welding operation.

The universal seam welder is shown here set up for longitudinal work. To change it for making circumferential welds, the upper assembly is rotated through 90 deg. and the lower replaced.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
Annual General Meeting. West London Branch. Windsor Castle Hotel, King-street, Hammersmith, W.6. Tues., June 7, 7 p.m.
Annual General Meeting. South-East London Branch. Congregational Church Hall, Court-road, Eltham. Tues., June 7, 7.15 p.m.

BIRMINGHAM
Annual General Meeting. Birmingham Branch. Birmingham Chamber of Commerce, 95 New-street, Birmingham. Wed., June 8, 6.30 p.m.

BOLTON
Annual General Meeting. Bolton Branch. Balmoral Hotel, Bradshawgate, Bolton. Mon., June 6, 7.30 p.m.

BRADFORD
Annual General Meeting. Bradford Branch. Midland Hotel, Bradford. Wed., June 8, 7 p.m.

CARDIFF
Annual General Meeting. South Wales Branch. Angel Hotel, Westgate-street, Cardiff. Tues., June 7, 7 p.m.

ILFORD
Annual General Meeting. North-East London Branch. Angel Hotel, Ilford. Mon., June 6, 7.30 p.m.

LEEDS
Annual General Meeting. Leeds Branch. Great Northern Hotel, Leeds. Mon., June 6, 7 p.m.

NOTTINGHAM
Annual General Meeting. Nottingham Branch. Offices of the East Midlands Electricity Board, Smithy-row, Nottingham. Wed., June 8, 7.30 p.m.

OXFORD
Annual General Meeting. Oxford Branch. Y.M.C.A., 10 George-street, Oxford. Sat., June 11, 6 p.m.

PORTSMOUTH
Open Meeting. Portsmouth Branch. 598 Commercial-road, Mile End, Portsmouth. Tues., June 7, 7.30 p.m.

YORK
Annual General Meeting. York Branch. Picture House Café, Coney-street, York. Wed., June 8, 7.15 p.m.

Chemical Society

OXFORD
Lecture by Sir Robert Robinson, O.M. Oxford Branch. Physical Chemistry Laboratory, South Parks-road, Oxford. Wed., June 8, 8.15 p.m.

Incorporated Plant Engineers

LONDON
Discussion on "Work Study." London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., June 7, 7 p.m.

LIVERPOOL
"Liquid-Fuel Firing," by S. S. Whitehead. Merseyside and North Wales Branch. Royal Institution, Colquitt-street, Liverpool. Thurs., June 16, 7.15 p.m.

MANCHESTER
Open Meeting. Manchester Branch. Engineers' Club, Albert-square, Manchester. Tues., June 7, 7.15 p.m.

NEWCASTLE-UPON-TYNE
"Steam for Process," by L. G. Northcroft. North-East Branch. Roadway House, Oxford-street, Newcastle-upon-Tyne. Thurs., June 9, 7 p.m.

Institution of Civil Engineers

LONDON
Annual General Meeting. Corporate members only. Tues., June 7, 5.30 p.m.

Institution of Naval Architects

LONDON
"The Influence of Dimensions on the Behaviour of Partial Superstructure," by W. Muckle; and "The Strength of Corrugated Plating for Ships' Bulkheads," by J. B. Caldwell. Thurs., June 9, 4.45 p.m.

Royal Institution

LONDON
"Weather Forecasting: The Future Outlook," by Sir Graham Sutton. Fri., June 10, 9 p.m.

The Royal Society

LONDON
Discussion on "Radiative Balance in the Atmosphere," to be opened by H. S. W. Massey. Thurs., June 9, 11 a.m.

Women's Engineering Society

MANCHESTER
Annual General Meeting and Film Evening. Manchester Branch. Engineers' Club, Albert-square, Manchester, 2. Wed., June 8, 6.45 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.1. (SLOane 4622.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Women's Engineering Society, 45 Eastcastle-street, London, W.1. (LANgham 9571.)